ECONOMIC EFFICIENCY OF BEEKEEPING AND ITS IMPLICATIONS ON HOUSEHOLD INCOME AMONG BEEKEEPERS IN TABORA AND KATAVI REGIONS, TANZANIA

NICHOLAUS MUSIMU KUBOJA

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EXTENDED ABSTRACT

A study was conducted to evaluate the profitability, efficiency and adoption of improved beehives and its implications on household income among beekeepers in western Tanzania. Specifically the study focused on; profitability analysis, comparing between beekeepers using traditional and improved beehives. The study also compare the economic efficiency among beekeepers using improved beehives; analysed the adoption and income poverty impacts of improved beekeeping technologies; and investigated the underlying factors for honeybee colonies absconding and its financial implication among beekeepers. A structured questionnaire was the main tool for collecting data from a sample of 198 small-scale beekeepers. Out of these, 36 beekeepers were using improved beehives whereas 162 beekeepers comprised traditional beehives users. The household interviews were supplemented with interviews from the Focus Group Discussions (FGDs) and discussion with key informants. Both qualitative and quantitative data were collected and analysed using descriptive statistics. Analyses of Variance (ANOVA) along with budget analysis and profitability ratios were used to compare the profitability of using improved and traditional beehives. The study applied the stochastic profit frontier model to estimate the economic efficiency of small scale beekeepers in Tabora and Katavi regions. Variables in the stochastic profit frontier (SPF) model were normalized by the weighted average output price. To obtain the weighted average output price, the average output prices of honey and beeswax were calculated in correspondence to the total number of beekeepers who sold these products. Thereafter, using the Excel function “SUMPRODUCT()” command, the average weighted output price was calculated. To analyze the adoption and impacts of improved beehives on household income among beekeepers the propensity score matching and endogenous switching regression models were used. A beekeeper was considered as an adopter if they had bought or constructed at least one improved beehives and used it. Meanwhile, a non-adopter was a beekeeper who had never bought or constructed improved hives for their use. The findings revealed that improved beehives were more productive than traditional beehives. However, both beekeeping systems were profitable ventures. Profit margins among beekeepers using improved beehives are highly sensitive to the cost of labour and other material for bee hives. Reducing the cost of these inputs can significantly increase profit levels from beekeeping. Thus, interventions to reduce the cost of labour and ease the availability and cost of other materials associated with all essential inputs for beekeeping are important means to enhance economic efficiency among small scale beekeepers. Small scale beekeepers using improved beehives in the study area had a mean economic efficient of 91.7%. This implies that there is room for improvement by about 8.3% without changing the profit frontier. The numbers of visits by beekeeping extension officers and access to beekeeping training were the main factors that significantly influenced economic efficiency of small scale beekeepers. The probit model estimates coefficients of the factors hypothesized to influence the adoption of improved beehives. The findings showed that adoption is significantly influenced by age of the household head, years of formal schooling, access to credit, access to extension services, training and experience in beekeeping. This implies that easy access to institutional support such as extension services, financial services and capacity building would play the most important role in the adoption of improved beekeeping technology leading to reduced income poverty. Using propensity score matching and endogenous switching regression models, the analysis further shows that the adoption of improved beehives leads to significant gains in beekeeping annual income. The magnitude of the estimated effects was almost similar across both econometric models. Shortage of bee forage, poor infrastructures, presence of bee pests, diseases and predators, unreliable markets, inadequate capitals and beekeeping facilities were the main constraints affecting the honey sub sector in the study area. Absconding of honeybee colonies was identified as a serious problem, affecting more than 854.8% of the beekeepers, causing an average annual income loss of TZS 2,894,555.89 (equivalent to US$ 1,822.5) and TZS 1,797,105.02 (equivalent to US$ 1,131.5) among beekeepers using traditional and improved beehives, respectively.

On the basis of these findings, the study concludes that despite the challenges and constraints facing the beekeeping sector, the enterprise was economically viable. Beekeepers who adopted improved beehives had higher earnings per hive than the non-adopters. It was also clear that beekeepers improved beehives are economically efficient, ranging from 18.6% to 98.4% and a mean of 92%. This implies, still there is a room for improvement (8%) for beekeepers already using this technology. In view of these findings there is a need for policies and strategies aimed at enhancing the adoption of improved beehives among non-adopters. This can be achieved through more efficient extension services, access to credit to facilitate acquisition of improve beehives and associated tools for harvesting honey. There is also need to improve training beekeepers on technical and business aspects of the enterprise including market and improving the marketing information system. Also, the study recommends provision of sufficient training to beekeepers on best practices to reduce absconding of honeybee colonies from their hives. There is also need to improve infrastructure such as main roads and water facilities within apiary sites. In order to improve the acquisition of services and benefit from collective marketing, beekeepers are encouraged to establish cooperative, which will also facilitate access to credit to beekeepers.

Key words: *Profitability analysis, economic efficiency, adoption and impacts, beekeeping, absconding*

DECLARATION

I, NICHOLAUS MUSIMU KUBOJA, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work and that it has neither been submitted nor is it being concurrently submitted for degree award in any other Institution.

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NICHOLAUS MUSIMU KUBOJA **Date**

(PhD. Candidate)

The above declaration is confirmed

_______________________ __________________________

Prof. Isinika, A.C. **Date**

(Supervisor)

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Prof. F.T.M. Kilima **Date**

(Supervisor)

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DEDICATION

This work is dedicated to GOD the ALMIGHTY the Creator and giver of life to every living creature.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADAP	Association for Development of Protected Areas Project
ANOVA	Analysis of Variances
ATT	Average treatment effect on the treated
ATU	Average treatment effect on the untreated
B/C	Benefit –Cost ratio
CIFOR	Centre for International Forestry Research
COSTECH	Tanzania Commission for Science and Technology
CRE	Correlated Random Effects
ESR	Endogenous Switching Regression
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GM	Gross Margin
ICE	Institute of Continuing Education
KOICA	Korea International Cooperation Agency
KTBH	Kenyan Top Bar Hives
LGAs	Local Government Authorities
MLE	Maximum Likelihood Estimation
MNRT	Ministry of Natural Resources and Tourism
NGOs	Non-Governmental Organizations
NI	Net Income
NNM	Nearest Neighbour Matching
OLS	Ordinary Least Square
OR	Operation Rate
PE	Profit Efficiency

PI	Profitability Index
PL	Profit Loss
PSM	Propensity Score Matching
RRI	Rate of Return on Investment
SMEs	Small and Medium Enterprises
SPSS	Statistical Package for the Social Sciences
TASAF	Tanzania Social Action Fun d
TAWIRI	Tanzania Wildlife Research Institute
TC	Total Cost
TFC	Total Fixed Cost
TR	Total Revenue
TTBH	Tanzanian Top Bar Hives
TVC	Total Variable Cost
TZS	Tanzanian Shillings

CHAPTER ONE

1.0 INTRODUCTION

1.1 Beekeeping Sector

In Tanzania and other African countries, beekeeping plays a vital role for achieving the millennium development goal of alleviating poverty (MNRT, 1998; Hausser and Mpuya, 2004; Pender *et al*., 2006; Russell, 2008). Honey and other bees' products are important for food, traditional and formal pharmaceutical industries; if sold bee products provide cash incomes (Wakjira, 2010; Ingram and Njikeu, 2011). Thus, across African countries including Tanzania the local and international markets for honey and other bees' products are opening rapidly (Ingram and Njikeu, 2011). Apart from being a source of income for poverty reduction, beekeeping is also said to improve conservation of forests and woodlands (MNRT, 1998; Hausser and Mpuya, 2004; Pender *et al*., 2006; Russell, 2008).

The role of beekeeping in forests and woodlands conservation is well acknowledged in the development literature (Appiah *et al*., 2015; Albers and Robinson, 2011). Beekeeping can contribute to conservation of forests and woodlands because it incentivizes beekeepers to protect the forest and woodlands to ensure their harvests. This in turn inhibits forest clearance, protect and aid the management of forests, and provide vital pollination services for forest ecosystems and agriculture (Hausser and Mpuya, 2004; Brown, 2006; Russell, 2008). However, the potential of beekeeping to contribute to poverty reduction and conservation of forests and woodland depends on whether traditional or improved beekeeping technologies are used.

Tanzania is endowed with a favourable environment for the production of honey, beeswax and other bee products. There are about 33.5 million hectares of forests and woodlands that are scattered throughout the country which are ideal for carrying out beekeeping activities (Backeus *et al*, 2006; Marjo and Feek, 2010; Songo, 2015). Out of these, 20.5 million hectares are unreserved forests and woodlands, while 13 million hectares of forest and woodland are forest reserves (Mwakatobe, 2007). Tanzania is also estimated to have about 9.2 million honeybee colonies whose production potential is about 138 000 tons of honey and 9200 tons of beeswax per annum (URT, 2012). Based on the average prices for the year 2011, that is, US $ 8 per kg of honey and US $ 16 per kg of beeswax the products are worth US $ 8 832 million and US $ 147.2 million, respectively. Currently, Tanzania produces approximately 9000 tons of honey worth TZS 27 billion and 600 tons of beeswax worth TZS 3 billion (URT, 2012). The current utilization of this potential is only about 6.5% annually (URT, 2013). Honey production in Tanzania is carried out using traditional methods that account for 99% of the total production of honey and beeswax in the country, and in that respect, approximately 95% of all hives are traditional made of log and bark hives (Kajembe, 1994). Other materials used for making bee hives include reeds, gourds and pots. In Tanzania beekeepers are estimated to reach 2 million rural people (URT, 2013). The prevailing low production of bee products in Tanzania is linked to poor markets, poor extension services and low use of and access to improved production technologies (Backeus and Ruffo, 2010; Namwata *et al.,* 2013; Igunda; 2013). Other factors leading to low production of bee products include shortage of bee forage, presence of pests, diseases and predators and honeybee colony absconding (Kihwele, 1985; Igunda, 2013; Kimaro *et al.,* 2013; Minja and Nkumilwa, 2016).

In Tanzania shortage of bee forage is mainly due to drought, population pressure related ecological impacts such as deforestation and expansion of agricultural land (Kimaro *et al.*, 2013). Deforestation and forest degradation in Tanzania are mainly due to shifting cultivation, settlements, traditional beekeeping practices and improper timber harvesting (Kimaro *et al.,* 2013).

1.2 Statement of the Problem and Justification for the Study

On the one hand traditional beekeeping technologies are considered to be less productive and they are said have negative impacts on forests and woodlands due to improper use of fire that cause wildfires and bark hives that kill trees within forests and woodlands (Kevan, 2015; Campbell *et al*., 2007). On the other hand, improved beekeeping technologies are promoted as being more productive and has no repercussion on forests and woodlands and is compatible with all other land uses (Fischer, 1993 cited by Syampungani *et al*., 2009). However, there is little or no empirical evidence regarding the productivity and profitability of improved beekeeping in Tanzania.

Nonetheless, studies across countries within and outside Africa still show low adoption of improved beekeeping technologies (Mwakatobe and Mlingwa, 2010; Nkojera, 2010; Gezahegn and Tadesse, 2001 cited by Birhan *et al*., 2015). This implies that attaining the dual goals attached to beekeeping in Africa and elsewhere will not be achieved until there is a significant increase in the adoption rate of improved beekeeping technologies among beekeepers. In Tanzania, since the adoption of the National Beekeeping Policy of 1998 (MNRT, 1998) different stakeholders are promoting improved beekeeping technologies. The main goal of the beekeeping interventions is to reduce poverty and enhance sustainable utilization of forests and woodlands. However, most of such interventions have been futile as the adoption rate has been disappointingly low (Mwakatobe and Mlingwa, 2010; Nkojera, 2010). The literature identifies several factors that are likely to hinder adoption of improved beekeeping technologies; these include uncertainty among potential adopters about potential gains vis-à-vis the cost of adoption (Pannell *et al*., 2006; Koundouri *et al*., 2006), capability to afford the investment costs required to adopt the technology (Fisher and Kandiwa, 2014; Kurkalova and Zhao, 2006) and inadequate knowledge on how to use the technology (Bravo and Ureta, 2006; Ojiem *et al*., 2006).

Most of these factors have not been empirically verified in Tanzania, suggesting the need for studies in this area.

Previous studies on beekeeping have focused on value addition, design of improved beehives, economic value and marketing of different bee products, and beekeeping management practices (TAWIRI, 1997, 1998, 2002, 2004, 2006; Mwakatobe and Mlingwa, 2005; Swai and Oduol, 2003). Other studies have focused on women and youth participation in beekeeping and associated value chain activities (MMA, 2007; Mkamba, 2006). Along this line, some studies found that many of the farmers perceive that improved beehives are too costly to afford. Hence, they tend to maintain many traditional beehives and only a few improved beehives. It is not clear whether perception about high investment cost outweigh the increase in productivity associated with improved beehives. This thesis focused on a comparative analysis of profitability of beekeeping using traditional and improved beehives, which formed Paper I.

Studies in Tanzania have documented that the contribution of beekeeping sector to the economy is estimated at 100 000 metric tons of honey and 66 000 tons of beeswax. This is lower than the sub-sector’s potential by almost 90% (MNRT, 2010). The need to improve beekeeping productivity is crucial given the booming local and international markets (Ajibola *et al*., 2012). Low productivity of beekeeping is ascribed to the use of traditional beehives and inefficient beekeeping practices (Husselman *et al*., 2010; Mmasa, 2007). Both types of beehives and other beekeeping practices as influenced by the knowledge of beekeepers interact in an additive manner to influence their technical efficiency, which in turn influences their productivity (Affognon *et al*., 2015). However, the economic efficiency of using improved beehives among small scale beekeepers has not been studied in Tanzania. Thus, motivated by Affognon *et al*. (2015), it was perceived imperative to analyze economic efficiency for beekeepers applying different levels of beekeeping management practices in conjunction with improved beehives. This thesis addressed this issue through Paper II of this thesis which focused on deriving a statistical measure of profit efficiency among small scale beekeepers in Tanzania using a stochastic profit frontier approach.

With only a few exceptions (Nkojera, 2010; Affognon *et al*., 2015) most previous studies on adoption of improved beekeeping technologies in Africa have focused on estimation of simple adoption rate at the expense causation analysis, relationships between factors and impacts. As such these studies fail to provide concrete policy recommendations to enhance the adoption of improved beekeeping and their positive impacts. Most studies on the adoption and impacts of improved beekeeping technologies in Tanzania applied single econometric models of adoption (Mwakatobe, 2000; Nkojera, 2010), which fail to reveal the causation of adoption factors or counterfactual effects in estimating the level of impacts. In order to address this knowledge gap, Paper III of this thesis applied multiple econometric models to analyse adoption of improved beehives and their associated impacts.

Apart from the low rate of adoption of improved beehives, the low production of bee products in Tanzania is associated with shortage of bee forage, presence of pests and predators, inadequate supply of beekeeping facilities and unreliable market along with poor access to extension services (Backeus and Ruffo, 2010; Namwata *et al.,* 2013; Igunda; 2013).Absconding of honeybee colonies has also been reported in most of beekeeping communities in Tanzania (Kihwele, 1985; Igunda, 2013; Kimaro *et al.,* 2013; Minja and Nkumilwa, 2016). However, little is known about its underlying factors for colony absconding and its financial implication, especially comparing between beekeepers using improved and those using traditional hives. Paper IV of this thesis was undertaken to address this gap by assessing honeybee colonies absconding and its financial implication among beekeepers in selected study districts within Tabora and Katavi regions in western Tanzania.

All the analyses are based on case studies from beekeepers in four districts within Tabora and Katavi regions to assess the profitability of beekeeping using traditional and improved beehives (Paper I), economic efficiency among beekeepers (Paper II), adoption and income poverty impacts of improved beekeeping technologies (Paper III) and honeybee colonies absconding and its financial implications (Paper IV).

1.3 Objectives of the Study

This study is guided by one general objective and four specific objectives as listed below.

1.3.1 Overall objective

The study's overall objective is to evaluate the profitability, efficiency and adoption of improved beehives and the implications on household income levels among beekeepers in western Tanzania. This general objective was accomplished by pursing four specific objectives as listed below.

1.3.2 Specific objectives

i. To compare the profitability of beekeeping between beekeepers using improved and those using traditional beehives in the study area (Paper I).
ii. To examine the economic efficiency among beekeepers using improved beehives in the study area (Paper II).

iii. To assess the adoption factors and impacts of improved beehives on household income levels in the study area (Paper III).

iv. To investigate factors underlying honeybee colonies absconding and its financial implications among beekeepers in the study area (Paper IV).

1.4 Research Hypotheses

On the basis of the overall objective and specific objectives the study tested the following hypotheses:

(i) There is no significance difference in profitability between traditional and improved beehives used by small scale beekeepers in the study area.

(ii) Beekeepers using improved beehives are economically inefficient.

(iii) Socioeconomic characteristics of beekeepers have no influence on the adoption of improved beehives.

Apart from the three above hypotheses that were corresponding to specific objectives (i) to (iii), three research questions were addressed in correspondence to specific objective (iv). These were:

i.) What is the prevalence of beehive absconding by bee colonies in the study area?

ii.) What are the underlying factors for honeybee colonies absconding from hives?

iii.) What is the financial implication of honeybee colonies absconding on annual household income from beekeeping?

1.4.1 Theoretical and conceptual framework

1.4.2 Theoretical framework

The measurement of efficiency remains an important area of research both in developing and developed countries. It goes a long way to determine the profitability of an enterprise since any sector growth is linked to profit (Abdulai and Huffman, 2000). The relationships between efficiency, adoption impacts and the beekeeper’s characteristics have not been studied in Tanzania. Understanding these relationships will provide policy makers necessary information for designing programmes that can contribute to growth of the beekeeping sub-sector within the country through enhanced production efficiency.

Farrell (1957) defines efficiency as the ability to produce a given level of output at a lower cost. This definition disaggregates efficiency into three components; technical, allocative and economic. Technical efficiency is defined as the ability to achieve a higher level of output, given similar level of inputs. Allocative efficiency deals with the extent to which farmers make efficient decisions by using inputs up to the level at which their marginal contribution to production value is equal to the factor cost. Economic efficiency is the product of technical and allocative efficiencies. Naturally, it is possible for a firm to exhibit either technical or allocative efficiency without having economic efficiency. Both technical and allocative efficiencies are necessary conditions for economic efficiency.

Production functions have traditionally been used to examine efficiency of producers in many developing countries (Ojo, 2003). However, Yotopoulos and others argued that a production function approach to measure efficiency may not be appropriate when producers face different prices and have different factor endowments (Ali and Flinn, 1989 cited by Nganga *et al.,* 2010). This led to application of stochastic profit function models to estimate farm specific efficiency directly. This study will therefore provide a direct measure of production efficiency of beekeepers in Tabora and Katavi regions using a stochastic profit frontier and inefficiency model.

1.4.3 Conceptual framework

Figure 1.1 presents a schematic framework for the production efficiency of beekeeping using improved beehives and the impact of this efficiency on household income among beekeepers. The present study assumes that for some farmers, beekeeping is an important portfolio among their sources of livelihood. Such farmers behave as rational economic agents as they allocate resources for beekeeping in order to maximize profit which they achieve by producing the highest value of bee products at the least cost. This means they strive to operate on the production frontier for the technology they are using. The performance of individual beekeeper is however influenced by socioeconomic characteristics which include age, sex, education, wealth status, occupation, access to training as well as access to credit, markets and extension services.

As rational economic agents, the beekeepers allocate their scarce resources to a technology which maximize profit. On this basis, they would be expected to opt for improved beehives which are presented as a better technology with the expectation of getting a higher volume of production of bee products, hence higher value. For any given technology, beekeepers will be deemed technically inefficient if their production falls below the production frontier curve for that technology. Thus, to achieve the most efficient production level, factors that reduce the beekeeper's efficiency level should be addressed. Higher efficiency from beekeeping is assumed to increase household income, nutrition and living standards which in turn support labour productivity resulting in better health and the well-being of the household members. This framework therefore views income poverty both as an effect and cause of low productivity.

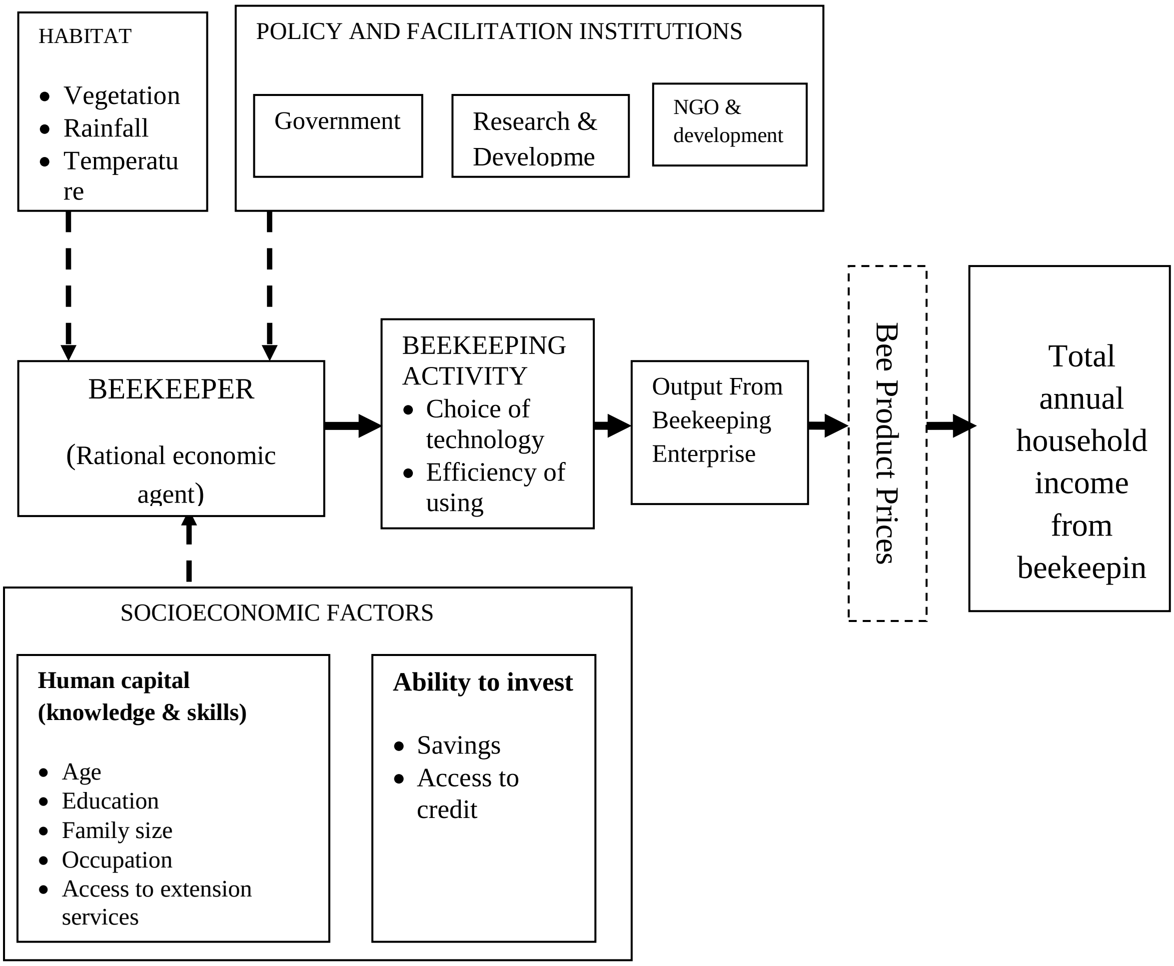

Figure 1.1: Conceptual framework of the study

1.5 Organization of the Thesis

The thesis is divided in to seven related chapters. Chapter 1 is the introduction which gives background information about the thesis, research objectives, problem statement, theoretical and conceptual frameworks as well as the approaches. Chapter 2 reviews the literature showing challenges in the beekeeping sector, factors influencing the adoption of improved beekeeping technologies, efficiency among beekeepers, adoption and impacts of improved beekeeping technologies. Chapter 3 presents results on comparative profitability of using improved and traditional beehives among beekeepers to demonstrate the economic viability of the two enterprises. Chapter 4 examines the determinants of profit efficiency among beekeepers. The chapter also estimates the economic efficiency of using improved beehives. The analysis of adoption and impacts of using improved beehives on household income is discussed in Chapter 5. An assessment of honeybee colonies absconding and its financial implication among beekeepers is given in Chapter 6, while conclusions, recommendations, and future research agenda are summarized in Chapter 7. Chapter 3 is published in Huria Journal of the Open University of Tanzania (Kuboja *et al.,* 2016). Chapter 4 is published in the Journal of Development Studies Research (Kuboja *et al.,* 2017). Chapter 5 and 6 are publishable manuscripts under review in World Development Perspectives Journal published by Elsevier and Journal of Apicultural Research published by Taylor & Francis, respectively. These chapters are presented here after minor modifications to conform to the theme of this thesis.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Factors Affecting the Production of Honey among Beekeepers

Honeybees have a lot to offer in terms of agricultural products, ecosystem services as well as in improving the welfare of human being. However, bees are exposed to a number of threats such as climate change, reduced biodiversity, and invasive species that reduce their quality of health and longevity (Mumbi *et al.*, 2014; UNEP, 2010; Pokhrel, 2009). According to Mumbi *et al.* (2014) and Pokhrel (2009), predators, parasites and diseases are some of the factors that have negative impact on beekeeping, thus reducing honey production. These preditors and parasites may feed on the honeybees, thus decreasing the population of bees hence lowering production. Parasites and diseases also affect beekeeping in other ways. For instance disease will eventually lower production whenever honeybees succumb to many diseases thereby reducing the production of honey. Honeybees can also be affected when collecting nectar from plants that had been treated with high concentration of pesticides because such treated nectar kills the bees thereby lowering production in terms of output. Beekeepers should therefore control damage on vegetation planted close to the project area, by using less concentrated pesticides on such plants or crops (Pokhrel, 2009).

Meanwhile, demographic factors of beekeepers such as age can be a factor in beekeeping, during harvest times or other difficult operations in most cases only young adults are able to handle all the operations requiring labour. Some literature points out that only those individuals who are still young (20-40 years old) can be able to harvest honey from trees while those who are above 50 years are often not able to do so (Pokhrel, 2009). Gender is another factor that affects honey production. Most women find it difficult to harvest their produce due to bees' stings. Moreover, the division of labour that exists in most of beekeeping societies limits the participation of women from some of beekeeping operations (Yahaya and Usman, 2008). Lack of technical know-how is another factor in the sense that beekeeping is mainly practiced in rural areas where most people are less educated in agricultural practices due to the fact that they are unable to get funds for their education thus limiting the harvested honey yields (Yahaya and Usman, 2008). According to Gamez *et al.* (2004), poor feeding of bees especially during winter affects honey production. When the colony is not well fed, it will leave the area thereby reducing the yield. The literature states further that for honey to be increased, it is essential that there should be a well populated colony within an area where there is abundant nectarous flora (Gamez *et al.,* 2004). In addition, Namwata *et al.* (2013) identified unreliable markets, lack of knowledge and skills, and lack of capital as the main challenges among beekeepers in Hanang district, Tanzania.

2.2 Profitability Analysis of Beekeeping

Studies across different African countries have consistently identified beekeeping as one of the profitable enterprise in rural areas. In Nigeria, Udeagha *et al.* (2016) reported a profitability index of 0.59 and an operating ratio of 0.16 which signify significant net income gain and larger gross income over total variable cost. The profitability index of 0.59 imply that for every 1Naira (Nigerian currency) used about 0.56 returned to the beekeeper as a net income. Meanwhile, an operating ratio of 0.16 (which is equivalent to 16%) indicates that only 16% of the sale revenues would be used to cover operating expenses. Tijani *et al*. (2010) reported similar results in the same country. Similarly, Melaku (2005) using partial budget analysis indicated, when added cost (reduced return) and increased return (reduced cost) accounted for both the home made and institutionally prepared Kenya Top Bar Hives (KTBH), it was found that both types of KTBH are beneficiary and remunerative.

2.3 Review of the Frontier Function Methodology for Efficiency Estimation

Efficiency studies following the frontier function can be divided into two main categories according to the type of methodology used. They can either be deterministic production frontiers or stochastic production frontiers. In turn studies using deterministic models that are subdivided into parametric and non-parametric frontiers while those based on stochastic models are subdivided into cross-sectional, panel data and dual frontiers. However, all stochastic frontiers are of the parametric type. Apart from methodological aspects and efficiency levels estimation, relationship between efficiency and various socioeconomic variables are also examined. Two approaches are commonly used to examine these relationships. One is to compute correlation coefficients or to conduct simple non-parametric analyses. The other route usually referred to as the second step analysis. First, farm level efficiency is measured based on a regression model and then efficiency is expressed as a function of socioeconomic attributes (Bravo-Ureta and Pinheiro, 1997).

For the purpose of this study, the literature review focused on cross-sectional frontier studies both in agricultural and beekeeping sectors. Kalirajan (1984) examined how the efficient use of new technology affected production levels among 81 Philippine rice farmers, using a translog stochastic production frontier. The results revealed a wide variation in technical efficiency across farms ranging from 42% to 91%, with only 30% of the farmers operating close to the frontier. The results of a second step model showed that the number of farm visits by extension agents was significant in explaining the wide variation in the observed levels of technical efficiency. Ekai Ayake and Jayasuria (1987) similarly examined efficiency for a sample of 123 Sri-Lankan rice farmers. The sample was divided into head and tail, according to whether the farm had good (head) or poor (tail) water access. Separate stochastic Cobb-Douglas production frontiers were estimated for each group using the maximum likelihood analytical method. The results suggested that there was no significant technical inefficiency for farmers with better access to water (head). However, for poorly situated group (tail) there was significant technical inefficiency. In a second step analysis, Ekai Ayake and Jayasuria (1987) found that literacy, experience, and credit availability had a significant positive impact on the technical efficiency level of the tail farmers. This was also true when analyzing the tail farmers' "apparent" allocative efficiency (AAE), defined as the ratio of profit at predicted output to maximum profit.

Taylor and Shonkwiler (1986) conducted a comparative study to evaluate the performance of a deterministic frontier with that of a stochastic frontier assuming a Cobb-Douglas production model. The frontier parameters were estimated by the maximum likelihood method, assuming a gamma distribution for the former and a half normal distribution for the latter. The results showed that the average technical efficiency estimates from the stochastic frontier for participants and non-participants were much higher (71% and 70%) than those obtained from the deterministic frontier specification (17% and 5.9%), respectively. Given the large difference between the two models and the extremely low technical efficiency estimates obtained by the deterministic specification, the authors concluded that the latter produced misleading results. Msuya *et al.* (2008) used a stochastic frontier production model to estimate the levels of technical efficiency among smallholder maize farmers in Tanzania. Results revealed that the technical efficiency of maize farmers ranged from 1.1% to 91% with a mean of 60.6%. Low level of education, poor access to extension services, limited capital, land fragmentation and unavailability and high input prices were found to have a negative effect on technical efficiency.

Application of the stochastic production frontier via a Cobb-Douglas production function for estimation of technical efficiency of the beekeeping sector has been reported by Abdul-Maliki and Mohammed (2012) in Ghana; Olarinde *et al.* (2008) and Aburime (2006) in Nigeria.

2.4 Adoption and Impact of Improved Beekeeping Technologies

2.4.1 The process of adoption of technologies

Analyzing the adoption and impacts of the improved beekeeping technologies was one of the objectives of this study. However, studies that particularly focused on this aspect in Tanzania are few; a review of such studies was therefore done worldwide and is presented in this section. This review serves as a reference for the identification of variables deemed important for this analysis.

According to Feder *et al.* (1985), adoption may be defined as the integration of an innovation into farmers' normal farming activities over an extended period of time. The authors classified adoption into farm level adoption and aggregate adoption. They further made a distinction between models of individual adoption (farm-level), which refer to static character of technology transfer; and models of aggregate adoption, which are dynamic and derive analytically the behavior of the diffusion process over time. The frequency distribution of adopters over time tends to follows a bell-shaped curve and its cumulative frequency looks like the S-shaped curve (Rundquist, 1984).

Adoption at the farm level by individual farmers is defined as the degree of use of a new technology in the long-run equilibrium when the farmer has full information about the potential of the new technology (Feder *et al.,* 1985). In the context of aggregate adoption behavior, the same authors defined the diffusion process as the spread of a technology within a region. They further observed that, immediate and uniform adoption of innovation in agriculture is quite rare. In most cases adoption behavior differs across socio-economic groups and over time. Some innovations have been widely accepted while others have been rejected or being adopted by only a small group of farmers. Mosher (1979) reported that because of fear of risks associated with the introduction of new technologies, at early stages, few adopters acquire full information. In this respect, Bayerlee and Hass de polance (1986) also reported that the adoption pattern of a particular component of a technology is a function of profitability, riskiness, divisibility, or initial capital, complexity and availability.

2.4.2 Empirical studies on improved beekeeping technology adoption

The contribution of new technology to economic growth can only be realized when the new technology is widely diffused and used. According to Hall and Khan (2002), decisions to begin using the new technology are often the result of a comparison of the uncertain benefits of the new invention with the uncertain costs of adopting it. In the case of consumers, the benefits are the increased utility from the new good, but may also include intangible factors as the enjoyment of being the first on the block with a new good, the availability of complementary skills and inputs, the strength of the relation to customers, and the importance of network effects. The authors remarked that understanding the factors affecting this choice is essential both for economists studying the determinants of growth and for those who produce such technologies.

A number of improved beekeeping technologies adoption studies have been conducted worldwide by different researchers. This section summarizes results and implications synthesized from different studies that assessed adoption and impacts of improved beekeeping technologies.

Gorfu (2005) conducted a study in Ambasel Woreda of Ethiopia using the Logit model to identify factors influencing adoption of Kenyan Top Bar Hive (KTBH) among beekeepers. The results revealed that beekeeping experience, perception of timely supply of the technology, visits to the apiary and extension contact significantly influenced the adoption of KTBH. The implication of this study is that for maximizing its utilization and impacts the target should be experienced beekeepers, apiary visits, timely supply of the technology and improving the extension services.

Gebremichael and Gebremedhin (2014) reported that off-farm activities, beekeeping experience, distance to the market and the frequency of extension contacts were significant factors in explaining the adoption of improved box hive technology among small scale beekeepers in Northern Ethiopia. The study concluded that these factors need to be considered by policy makers and development planners for improvement when setting up policies and strategies for honey production improvement.

Meanwhile, (Nkojera (2010) found that access to extension services, knowledge and beekeeping training had positive and significant effects on the adoption of improved beekeeping technologies and practices in Tanzania. Similar results have been reported from Uganda (Mujuni *et al*., 2012) and Ethiopia (Wodajo, 2011). Analysis of these studies clearly show that determinants of adoption of improved beekeeping technologies and practices revolve around characteristics of the technology, features of the farming system, market and policy environments as well as socio-economic characteristics of the decision-making unit. Overall, these studies suggest that efforts to enhance adoption and impacts of improved beekeeping technologies should focus on empowerment of beekeepers with knowledge and skills; ensuring availability of modern technologies and increasing accessibility of credit facilities among beekeepers.

CHAPTER THREE

3.0 COMPARATIVE ECONOMIC ANALYSIS OF BEEKEEPING USING TRADITIONAL AND IMPROVED BEEHIVES IN THE MIOMBO WOODLANDS OF TABORA AND KATAVI REGIONS, TANZANIA

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CHAPTER FOUR

4.0 DETERMINANTS OF ECONOMIC EFFICIENCY AMONG SMALL-SCALE BEEKEEPERS IN TABORA AND KATAVI REGIONS: A STOCHASTIC PROFIT FRONTIER APPROACH

[1]Kuboja, N.M. [2] Isinika, A.C. and [3]Kilima, F.T.M.

[1]Ministry of Agriculture Food Security and Cooperatives, Tumbi Agricultural research Institute, P.O. Box 306, Tabora, [2]Sokoine University of Agriculture, Institute of Continuing Education (ICE), P.O. Box 3044, Chuo Kikuu, Morogoro, [3]Sokoine University of Agriculture, School of Agricultural Economics and Business Studies, P.O. Box 3007, Chuo Kikuu, Morogoro

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Abstract

This study applied the stochastic profit frontier model to estimate the economic efficiency of small scale beekeepers in Tabora and Katavi regions. The results show that the profit of small scale beekeepers was determined by changes in the cost of labour and other materials required for making beehives. Reducing the cost of these can significantly increase profit in beekeeping production. Small scale beekeepers were found to be economically efficient, with a mean efficiency of 92%. This implies that there is room for improvement by about 8% without changing the profit frontier. Contacts and follow up by beekeeping extension officers and access to beekeeping trainings on improved management practices were the main factors that had significant influence on economic efficiency of small scale beekeepers. Thus, regular and timely provision of extension services and beekeeping training among beekeepers can improve their practices.

Key words: *Economic efficiency, profit loss, small-scale beekeepers*

4.1 INTRODUCTION

The beekeeping sector in Tanzania generates about U$ 2 million each year from sales of honey and beeswax (MNRT, 2010). The sector and its related trade tends to be underestimated both in policy and planning. One reason may be the focus of rural development, in which crop production and livestock rearing are considered dominant income generating activities (Abrol, 2014; Abrol, 2013; Davis *et al.,* 2008; Ellis and Freeman, 2004). As a result, the contribution of beekeeping to employment and income generation is generally low. For instance in 2003, the sector contributed only 1% to the GDP (MNRT, 2004). According to MNRT (2010) the current contribution of the beekeeping sector to the economy is lower than its potential, which is estimated to be more than 100 000 metric tons of honey and 6600 metric tons of bee wax per annum. There is potential to increase production in this sector as there is low supply of bee products in Tanzania, especially in the urban areas. In terms of global importance, bee products have been widely used both as food and medicine (Ajibola *et al.,* 2012; Bogdanov *et al.*, 2008; Castaldo and Capasso, 2002). Honey has also become a major ingredient of human foods in Tanzania. The low production of bee products in Tanzania has been attributed to extensive use and low level of productivity of traditional beehives coupled with other inefficient traditional practices (Husselman *et al.,* 2010; Mmasa, 2007). Thus, increasing productivity that is normally associated with higher earnings would be an important endeavor for beekeepers in particular and for the national economy at large.

The purpose of this paper is to derive a statistical measure of profit efficiency among small scale beekeepers in Tanzania using a stochastic profit frontier approach. This analytical approach is used to measure the relative performance of the beekeepers by objectively computing a numerical efficiency value and ranking the scores. The analysis shows how close each beekeeper is to the "best-performers" on the frontier. Such analysis provides information that is useful in assessing the technical efficiency of each beekeeper and relates their score to socio-economic variable of beekeepers. Improving efficiency can improve the performance of a farm by distinguishing the "best-" and "worst" practices associated with the respective efficiency level. Furthermore, the paper investigates factors that determine the profit efficiency of the beekeepers. Understanding these factors is crucial for the design of policy interventions in the sector. The remainder of this paper is divided into three sections. Section 2 presents the theory of the stochastic frontier approach. Section 3 describes the methodology adopted for this study. Section 4 discusses the results followed by the conclusion and policy implications in the last section (5).

4.2 Theoretical and Analytical Framework

4.2.1 Theoretical framework

Efforts to provide tools for efficiency analysis were pioneered by Knight (1933), Debrew (1951) and Koopmas (1951). Koopmas (1951) provided a definition of technical efficiency while Debrew (1951) introduced the first measure as the "coefficient of resource utilization". Following Debrew's (1951) seminal paper, Farrell (1957) provided a definition of frontier production functions as the ability to produce a given level of output at the lowest cost. This definition distinguishes three types of efficiency namely technical efficiency, price or allocative efficiency and economic efficiency, which is the combination of the first two. Technical efficiency refers to the input-output relationship. A firm is said to be technical efficient if it is operating on the production frontier (Ali and

Byerlee, 1991). Conversely, a firm is said to be technically inefficient if it fails to achieve the maximum output from inputs. It is important to recognize other definitions of technical efficiency as applied to farm/firm. Mbowa (1996) defines an efficient farm as that which utilizes fewer resources than other farms to produce a given quantity of output. Yilma (1996) defines an efficient farm as the one which produces more output from the same measurable inputs than the other ones that produce less. Fan (1999) suggests that technical inefficiency is a state in which the actual or observed output from a given input mix is less than the maximum output possible.

Allocative efficiency deals with the extent to which farmers make efficient decisions by using inputs up to the level at which their marginal contribution to production value is equal to the factor cost. According to Rahman (2003), allocative efficiency relates to the degree at which inputs are optimally used, given the observed input prices. These components have been measured using the frontier production function which can be deterministic or stochastic. Deterministic frontier production function requires that all deviations from the frontier are attributed to inefficiency whereas in stochastic frontier production function it is possible to distinguish between random errors and differences in efficiency. Yotopoulos *et al.* (1970) argue that the production function approach to measure efficiency may not be appropriate when farmers face different prices and have different factor endowments. Similarly, Ali and Flinn (1989) argue that the production function framework fails to capture inefficiencies due to differences in factor endowments as well as input and output prices across different farms. As a result, farms may exhibit different "best practices" production functions and may even operate at different optimal points. This implies that the use of a more flexible profit function model which directly estimates farm-specific efficiency is an ideal approach to account for these differences (Kumbhakar, 2001; Rahman, 2003; Ogundari, 2006).

The flexible profit function model combines technical, allocative and scale efficiency measures into one system, thereby resulting into more efficient estimates through simultaneous estimation of the system. Any errors in the production decision are assumed to be translated into lower producers' profits (Ali *et al.,* 1994).Unlike the production function approach, the profit function model considers the ratio of relative input and output prices that accounts for allocative efficiency.

Profit functions have been estimated using different functional forms, including the Cobb-Douglas and more flexible functional forms such as the normalized quadratic, normalized translog and the generalized Leontief. It is important to note the main limitation of the translog model is its susceptibility to multicollinearity and potential problems of insufficient degrees of freedom owing to the presence of interaction terms (Ogunniyi, 2011). Despite its shortcoming, the translog model has been extensively used to estimate farm efficiency (Hyuha, 2006; Nwachukwu *et al.,* 2007; Ogunniyi, 2011). However, the Cobb-Douglas functional form has been more frequently used to estimate farm efficiency (Ogundari, 2006; Sunday *et al.,* 2012; Oladeebo and Oluwaranti, 2012) as it is less susceptibility to multicollinearity.

In terms of estimation, the stochastic frontier model has often been estimated using two procedures; the two-stages and one-stage procedure. In the two-stage procedure, the predicted efficiency scores are regressed against a number of household and farm characteristics to explain the observed differences in efficiency among farms. However, the procedure has been criticized for being inconsistent with assumptions regarding the independence of the inefficiency effects (Coelli, 1996).Thus, the one stage procedure is often more preferred.

To estimate the stochastic frontier model the inefficiency effects must be defined as a function of the farm specific factors, and then incorporated directly into the Maximum Likelihood Estimation (MLE) where both the production frontier and the inefficiency effect models are simultaneously estimated as a one-stage process. Battese and Coelli (1995) extended the stochastic production frontier model by estimating it as a linear function of explanatory variables. The advantage of this linear function is that it allows for the estimation of farm specific efficiency scores and factors explaining differences in efficiency among farmers in a single stage estimation procedure. The current study adopts the Battese and Coelli (1995) model where a profit function is assumed to be a linear function that can be estimated as a stochastic frontier model.

4.2.2 Analytical framework

According to Battese and Coelli (1995) the stochastic profit frontier model is therefore defined as:

$$\pi_i = f(P_i, Z_i), \exp(\varepsilon_i), where \qquad \varepsilon_i = v_i - u_i \qquad (1)$$

Note that $i = 1,2,3,...,n$ is the number of beekeepers in the sample; π_i is the normalized profit of the i^{th} beekeeper. The normalized profit is defined as gross revenue minus the variable cost which is then divided by farm-specific output price; P_i is the vector of variable input prices for the i^{th} beekeeper divided by the output price; Z_i is the vector of fixed factor for the i^{th} beekeeper; ε_i is an error term. Note that v_i is assumed to be independently and identically distributed following a normal distribution i.e. $iidN(0, \sigma_v^2)$ while u_i is a non-negative random variables associated with inefficiency in production. This inefficiency is assumed to be independently distributed with truncation at zero of the normal distribution with mean $\bar{u}_i$ ($\bar{u}_i = \delta_0 + \sum_{d=1}^{j} \delta_{id} W_{id}$) and variance ($\sigma^2 = \sigma_v^2 + \sigma_u^2$).

Note that W_i is the j^{th} explanatory variable for $d = 1,2,3,..., j$ is associated with inefficiencies of the i^{th} beekeeper while δ_0 and δ_d are unknown parameters to be estimated. The stochastic error term consists of two independent elements $(v \text{ and } u)$. The element v accounts for random variations in profit attributable to factors beyond the beekeeper's control. A one sided component $u \geq 0$ reflects economic efficiency relative to the frontier. Thus, when $u = 0$, it implies that farm profit lies on the efficiency frontier (i.e. 100% efficiency) and when $u > 0$, it implies that the farm profit lies below the efficiency frontier. Both v and u are assumed to be independently and normally distributed with zero mean and constant variance. Thus, economic efficiency of an individual beekeeper is derived as the ratio of the observed profit to the corresponding frontier profit given the price of variable inputs and the level of fixed factors of production for a particular beekeeper. Therefore, economic efficiency of the i^{th} beekeeper is defined as:

$$EE_i = E[\exp(-u_i)/\varepsilon_i] \quad \text{...} (2)$$

But $u_i = \delta_0 + \sum_{d=1}^{j} \delta_d W_d$ .... (3)

All variables in equation (2) and (3) are as previously defined. Substituting equation (3) into equation (2) yields;

$$EE_i = E[\exp(-\delta_0 - \sum_{d=1}^{j} \delta_d W_d)/\varepsilon_i] \quad \text{..} (4)$$

Where EE_i is the economic efficiency of the i^{th} farm and E is the expectation operator, which is achieved by obtaining the expressions for the conditional expectation of u_i given the observed value of ε_i. The maximum likelihood method is used to estimate the unknown parameters where the stochastic profit frontier and the inefficiency effects functions are estimated simultaneously. The likelihood function is expressed in terms of the variance parameters as: $\sigma^2 = \sigma^2{}_v + \sigma^2{}_u$ and $\gamma = \sigma^2{}_u / \sigma^2$ (Battese and Coelli, 1995). The variance (σ^2) is a measure of the overall fit and correctness of the specified distribution of the composite error term while gama (γ) tests whether inefficiency exists.

4.3 METHODOLOGY

4.3.1 Study area and sampling

This study was conducted in Urambo, Kaliua and Sikonge districts in Tabora region as well as in Mlele district in Katavi region. The two regions fall within the miombo ecosystem, which is famous for beekeeping in Tanzania. Since 1999, a number of government agencies, non-government organizations and development projects have intervened in various ways to improve the production of bee products by introducing improved beekeeping technologies. In Sikonge district for example, improved beekeeping technologies such as the use of transitional and commercial beehives were introduced and promoted by the District Council, Tabora Regional Office, Honey King Ltd, and the Korea International Cooperation Agency (KOICA). In Urambo district, improved beehives were introduced by the Tanzania Social Action Fund (TASAF) whereas in Mpanda district the Association for Development of Protected Areas Project (ADAP) pioneered the introduction of improved technologies among beekeepers (Hausser and Mpuya, 2004).

The four districts were purposively selected based on the predominance of improved beekeeping practices among beekeepers. A total of 198 small scale beekeepers were selected using a random sampling technique from the sampling frame consisting of 237 beekeepers. This sampling frame was established in collaboration with the district officials before the actual data collection. A structured questionnaire was used to collect primary data from the respondents which included socioeconomic variables such as sex, experience in beekeeping, age, education level, household size, number of beehives owned (both traditional and improved), the size (cubic centimeters) of improved beehives, production levels of various bees products and selling prices. The study also elicited information on the cost of production under improved beekeeping systems.

4.3.2 Empirical model

The study defines profit efficiency as any gain from operating on the profit frontier, taking into consideration farm-specific prices and factors of production. Farm profit is measured in terms of gross margin (GM) which equals the difference between the total revenue (TR) and the total variable cost (TVC). Mathematically this can be expressed as:

$$GM(\pi) = \sum TR - \sum TVC = \sum P_y Q - \sum P_x X \quad \ldots\ldots (5)$$

The modified stochastic Cobb-Douglas profit frontier model with inefficiency effect components was adopted following Battese and Coelli (1995) framework. All parameters in the two models were estimated using the Maximum Likelihood Estimator (MLE) in a single step. The explicit profit efficiency function for small scale beekeepers in the study area is specified as:

$$In\pi_i = \beta_0 + \beta_1 InC_{1i} + \beta_2 InC_{2i} + \beta_3 InC_{3i} + \beta_4 InX_{1i} + (v_i - u_i) \quad \ldots\ldots (6)$$

Where;

π_i = normalized profit for i^{th} beekeepers for $i = 1,2,3,...,n$ measured in Tanzanian shillings (TZS) per beehive, C_1 = cost of labour normalized by price of bee products (TZS/beehive), C_2 = cost of transport normalized by price of bee products (TZS/beehive), C_3 = other beekeeping cost normalized by price of bee products (TZS/beehive), X_1 stands for number of improved beehives harvested by the i^{th} beekeeper whereas β_0 and β_j stands for a constant parameter and coefficients of the j^{th} variable for $j = 1,2,3,4$; respectively.

The inefficiency model for estimation is specified as follows:

$$u_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + \delta_8 Z_{8i} + \delta_9 Z_{9i} + \vartheta \ldots\ldots (7)$$

Where;

u_i = the inefficiency effects; Z_1 = age of the beekeeper (years); Z_2 = number of household members; Z_3 = sex of the beekeeper (1= male, 0= female); Z_4 = number of household members who are fully engaged in beekeeping; Z_5 measures whether one has access to beekeeping extension services (yes= 1, otherwise= 0); Z_6 = number of visits to the beekeeper by the beekeeping extension officer (days per annum); Z_7 measures whether one has subscribed to any beekeeping association (yes=1, otherwise=0), Z_8 measures whether one has access to trainings on beekeeping (yes= 1, otherwise= 0), Z_9 = beekeeping experience (number of years), ϑ = error term, δ_0 = a constant term, $\delta_1, \delta_2, \delta_3, ..., \delta_9 =$ coefficient for z^{th} socioeconomic characteristics of beekeeper $, (z = 1, 2, ..., 9)$.

Profit loss (PL) due to inefficiency was also calculated. The loss is defined as the amount of profit that is not realized owing to beekeeper's inefficiency in production given the prices and fixed factor endowments. Such loss is calculated by multiplying the maximum profit by $(1 - PE)$, where PE is the maximum profit per beehive computed by dividing the actual profit per beehive of each beekeepers by his/her efficiency score.

$$PL = \pi_{\max}(1 - PE) \ldots\ldots (8)$$

Where $\pi_{\max}$ = maximum profit of an individual beekeeper (TZS/beehive), PL = profit loss due to inefficiency (TZS/beehive) and PE = profit efficiency.

4.4 RESULTS AND DISCUSSION

4.4.1 Descriptive statistics of variables in the stochastic profit frontier function

Table 4.1 presents descriptive statistics for different variables used in the stochastic profit frontier model. The average age of beekeepers' in the study area was about 49 years with a standard deviation of 16 year. This signifies that many of the beekeepers in the study area were in the productive age category. The average number of household members who were fully engaged in beekeeping was approximately one while the average beekeeping experience was approximately 16 years. Moreover, the mean number of improved beehives harvested by each beekeeper in the study area was eleven.

Table 4.1: Descriptive statistics of variables in the stochastic profit frontier function

Variable Name	Minimum	Maximum	Mean	Std. Deviation
Household members full involved in beekeeping	1.00	5.00	1.96	0.96
Total number Improved beehives harvested	1.00	140.00	11.05	18.94
Beekeeping experience (number of years)	2	60	16.27	16.42
Age of the beekeeper (years)	19.00	85.00	49.11	16.11
Others costs (TZS/beehive)	210.00	33 333.33	3495.00	5701.93
Transport costs (TZS/beehive)	333.33	150 000.00	10 137.00	25 068.47
Labour costs (TZS/beehive)	625.00	205 000.00	13 893.00	31 216.79
Actual Profit (TZS/beehive)	3800.00	115 000.00	41 451.00	27 960.79

Beekeepers in the study area earned about 41 451 TZS/beehive as profit with a standard deviation of 27 960.80TZS. The mean cost was estimated to be around 13 893 TZS/beehive, 10 137.00 TZS/beehive and 3495.00 TZS/beehive for labour, transport, and other inputs and/services, respectively. The profit per beehive had small standard deviation indicating that the variation in profit margin for most of the small-scale beekeepers in the sample was small (Table 4.1).

4.4.2 Maximum likelihood estimation of the stochastic Cobb-douglas profit frontier function

The stochastic profit frontier model was tested for its goodness of fit and accuracy of specified distribution assumption of the composite error term and existence of inefficiency among beekeepers. Results presented in Table 4. 2, reveal that the estimated value of gamma (0.95) is close to 1 and was significantly different from zero ($p<0.01$) implying existence of inefficiencies among small scale beekeepers in the study area. This indicates that 95% of disturbance in the stochastic profit frontier model is due to economic inefficiency of small-scale beekeepers attributable to their socio-economic characteristics. The estimated variance (σ^2) at 0.14 was significantly different from zero ($p<0.01$) indicating goodness of fit and correct specification of the distribution of the composite error term. The Log-likelihood Ratio test statistics of the one-sided error was 143.54 and was significant ($p<0.05$). Therefore the tests of null hypotheses for the absence of economic inefficiency $(H_0 : \gamma = \delta_0 = \delta_1 = ... = \delta_9 = 0)$ and that inefficiency effects are not stochastic $(H_0 : \gamma = 0)$ are all rejected ($p<0.01$). The implication of these findings is that the traditional average which would be obtained using the ordinary least squares (OLS) function is an inadequate representation of the results and economic inefficiency exist among small scale beekeepers in the study area.

The maximum likelihood estimation (MLE) of the parameters of the stochastic profit frontier model is presented in Table 4.2. The results revealed that coefficients for the cost of labour and other materials had a negative sign and both were statistically significant ($p<0.001$). A negative sign indicates that any reduction in the cost of these variable inputs would increase the profitability of beekeeping. The estimated function reveals that the cost of transport can potentially lower the profit of beekeepers in the study area. Results show that an increase of a 1TZS in transport cost can decrease the profit by 0.013TZS.

Table 4.2: Maximum likelihood estimates of parameters of the Cobb-Douglas Stochastic Profit Frontier function and profit inefficiency for small-scale beekeepers in the study area

Variables	Expected sign	Coefficients	Standard error	t-ratios
General model				
Constant		2.35	0.02	111.226
Normalized costs of labour (TZS/beehive)	+	-0.005***	0.005	-0.96
Normalized costs of transport (TZS/beehive)	-e	0.02	0.006	2.88
Normalized costs of other materials (TZS/beehive)	-	-0.003***	0.005	-0.53
Number of improved beehives harvested	+	0.007	0.001	13.22
Inefficiency model				
Constant		-2.57	0.32	-8.03
Age of the beekeeper	-	0.02***	0.01	1.91
Sex of the beekeeper	+	0.32***	0.41	0.79
Number of household member full engaged in beekeeping	+	0.31	0.08	3.78
Number of visits per year by the beekeeping officers	-	-0.19***	0.08	-2.48
Membership to beekeeping association	+	0.42***	0.23	1.86
Access to beekeeping improved management practices trainings	-	-1.13***	0.26	-4.33
Beekeeping experiences(number of years)	+v	0.02	0.005	4.37
Diagnostic statistics				
Sigma-square $\sigma^2 = \sigma_v^2 + \sigma_u^2$		0.14***	0.015	9.13
Gama $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$		0.95***	0.01	97.17
LR test of the one-sided error		143.54**		

Source: Computer print-out of FRONTIER 4.1

Note: ***, **, * implies significance at 0.01, 0.05 and 0.1 probability levels, respectively

4.4.3 Determinants of farm-specific economic efficiency

Table 4.2 also presents results of factors that explain variation in economic efficiency among small-scale beekeepers in the study area. With reference to specification of the inefficiency model in equation (7), a variable with a negative sign coefficient means it is positively related to economic efficiency and vice versa. In this case, the number of contacts with the beekeeping extension officers significantly explained the observed variation in economic efficiency among small-scale beekeepers. This implies the effectiveness of extension services that targeted small-scale beekeepers. This result is contrary to that of Shiferaw and Gebremedhin (2015) who found extension services having statistically insignificant effect of the technical efficiency of honey producers in Ethiopia. However, access to beekeeping training on improved management practices was found to be significantly explaining the variation in economic efficiency among small-scale beekeepers in the study area. This could be related to the advantage of getting technical knowledge and skills related to honey production as a result of training.

Meanwhile, sex of the beekeeper, membership in beekeeping association and experience in beekeeping were positively and statistically significant ($p<0.01$). This implies their negative influence on economic efficiency. The positive coefficient of the variable on sex implies that male beekeepers are more economically inefficient than female beekeepers. Similar findings were also reported by Oladeebo and Fajuyigbe (2007) among rice farmers in Nigeria whereby female farmers were more efficient than male farmers. However, other studies have revealed that females are as efficient as males in resource utilization (Quisumbing, 1996; Adesina and Djato, 1997; Kinkingninhoun-Mêdagbé *et al.,* 2010). Findings from the focus group discussion revealed that beekeepers with more experience in beekeeping (years) tend to take less risks and are less willing to adopt new innovations in order to produce more efficiently than those who are less experienced. The less experienced beekeepers tend to take more risks which in turn expose them to more productive innovations. Moreover, the less experienced beekeepers are also more receptive to new ideas or technologies than their experienced counterparts. The coefficient on the number of contacts with beekeeping extension officers and access to beekeeping training were negative and statistically significant, which indicates a positive influence on economic efficiency. The more contacts beekeeper has with extension services and more beekeeping training the more economically efficient the beekeeper becomes. This finding is in line with that of Olohungbebe and Daniel (2015) who noted adequate training on rudiments of beekeeping for improvement of resource use efficiency for honey production in Nigeria. The training and extension services the beekeepers receive tend to strengthen beekeepers' technical know-how thereby improving their beekeeping performance. Exposure to training and extension services allow beekeepers to acquire new insights into beekeeping.

4.4.4 Profit efficiency

The economic efficiency scores show that the majority (82.8%) of small-scale beekeepers have scores greater than 90% relative to the estimated economic efficiency frontier model (Table 4.3). The maximum economic efficiency score attained was 98% while the minimum was 19%. The mean economic efficiency was 92%, indicating potential for improvement by almost 8% through efficient use of the current technology. In general, most of the small-scale beekeepers are economically efficient.

Table 4.3: Economic efficiency scores of beekeepers in the study area

Economic efficiency scores	Frequency	Percent	Cumulative Percent
Less than 70	3	1.5	1.5
70 ≥80	3	1.5	3.0
81 ≥90	28	14.1	17.2
Greater than 90	164	82.8	100.0
Total	198	100.0	
Minimum	19		
Maximum	98		
Mean	92.03		
Standard error	0.689		
Standard deviation	9.701		

4.4.5 Profit loss in beekeeping using improved beehives

The inefficiency score translated into a profit loss per beehive that ranges from 560.00 TZS to 8271.00 TZS with a mean of 2633.20 TZS per beehive. A large proportion of small scale beekeepers (34.5%) experiencing this loss was within the "1001 – 2000" category of profit loss (Table 4.4).

Table 4.4: Profit loss in beekeeping

Profit loss	Frequency	Percent	Cumulative percent
≥1000	15	8.8	8.8
1001 - 2000	59	34.5	43.3
2001 - 3000	45	26.3	69.6
3001 - 4000	23	13.5	83.0
4001 - 5000	17	9.9	93.0
5001 - 6000	3	1.8	94.7
7001 - 8000	5	2.9	97.7
8001 - 9000	4	2.3	100.0
Total	171	100.0	
Minimum	560.00		
Maximum	8271.00		
Mean	2633.22		
Standard error	129.842		
Standard deviation	1697.901		

Source: Computed from MLE Results

4.5 CONCLUSION AND POLICY IMPLICATIONS

This study adopted the stochastic profit frontier model to estimate the economic efficiency of small scale beekeepers in Urambo, Kaliua and Sikonge districts of Tabora and Mlele district in Katavi region. The results show that the profit of small scale beekeepers is highly influenced to changes in the cost of labour and other materials required for beehives. Reducing the cost of these inputs can significantly increase profit levels from beekeeping. Thus, interventions to reduce the cost of labour and ease the availability and cost of other materials for all essential inputs for beekeeping are ideal means to enhance economic efficiency among small scale beekeepers. Small scale beekeepers in the study area had a mean economically efficient of 91.7%. This implies that there is a room for improvement by about 8.3% without changing the profit frontier.

Visits by beekeeping extension officers and access to beekeeping training are the main factors that significantly enhanced economic efficiency of small scale beekeepers. This finding suggests that policies aiming at increasing number of beekeeping extension officers and trainings on improved beekeeping management practices are expected to increase beekeepers’ efficiency probably due to scale effect. This can be achieved through regular training and timely provision of extension services among beekeepers. Thus, recruitment of beekeeping officers to serve at village and/or ward levels as well as investing in rural infrastructure such as roads would ease the transfer of relevant beekeeping information to flow from centres to the periphery location whereby majority of beekeepers dwell.

CHAPTER FIVE

5.0 ADOPTION AND IMPACTS OF IMPROVED BEEKEEPING TECHNOLOGY IN THE MIOMBO WOODLANDS OF TANZANIA

[1]Nicholaus Musimu Kuboja, [2]Isinika, A.C. and [3]Kilima, F.T.M.

[1]Ministry of Agriculture Food Security and Cooperatives, Tumbi Agricultural Research Institute, P.O. Box 306, Tabora,

[2]Sokoine University of Agriculture, Institute of Continuing Education (ICE), P.O. Box 3044, Chuo Kikuu, Morogoro,

[3]Sokoine University of Agriculture, School of Agricultural Economics and Business Studies, P.O. Box 3007, Chuo Kikuu, Morogoro

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Abstract

This paper analyzes the adoption and impacts of improved beehives on household income among beekeepers using improved beehives in western Tanzania using cross-sectional data obtained from a sample of 198 beekeepers. Out of these, 36 were using improved beehives and the remaining 162 were using traditional beehives. Using propensity score matching and endogenous switching regression models, the paper shows that adoption of improved beehives had a significant gain in household income accrued from beekeeping. An analysis of the determinants of adoption revealed age of the household head, years of formal schooling, access to credit, access to extension services, training and experience in beekeeping as key factors influencing adoption of improved beehives. This study supports the need for using improved beehives for improved productivity as well as household income among small scale beekeepers. Thus, efforts to improve access to and use of improved hive technologies should be part and parcel of income poverty reduction strategies among rural population in the study area where many households are depending mainly on beekeeping. The paper concludes that policies that enhance the diffusion and adoption of improved hives should be central to income poverty reduction strategies in Tanzania.

Keywords: *Adoption, endogenous switching regression, propensity score matching, household income, Tanzania*

5.1 INTRODUCTION

In Tanzania and other countries within miombo woodlands, beekeeping is vital for concurrent achievement of poverty reduction and forest conservation goals. However, attaining the dual goals from beekeeping depends on adoption of improved beekeeping technologies such as using improved beehives, protective gears, smokers and honey extractor (MNRT, 1998). Hence, it is important to replace traditional beekeeping practices because they are associated with low production (Mwakatobe and Mlingwa, 2010); and negative impacts on forests and woodlands due to improper use of fire that causes wildfire and bark hives that kill trees in forests and woodlands (Campbell *et al*., 2007). For example, in north-western Zambia, about 272,900 trees are debarked every year for making traditional beehives (Campbell *et al*., 2007). As opposed to traditional beehives, improved beehives have no repercussion on forests and woodlands and are compatible with all other land uses (Yirga *et al.*, 2012; Mwangi *et al.*, 2011; Jacobs *et al.*, 2006). Furthermore, improved beekeeping is more productive compared to traditional beekeeping technologies (Mwakatobe and Mlingwa, 2010).

Following the adoption of the National Beekeeping Policy of 1998 (MNRT, 1998) different national and international institutions have been promoting improved beekeeping technologies. The major goals of such beekeeping interventions are to reduce poverty while also enhancing environmental conservation. Over the last two decades, several studies have assessed the adoption of improved beekeeping technologies in Africa. Low adoption rates have frequently cited uncertainty among potential adopters regarding their profitability in relation to costs of adoption (Pannell *et al*., 2006; Koundouri *et al*., 2006). The uncertainty relates to beekeepers' inability to afford the cost of adoption and inadequate knowledge on how to use the technology. However, there is limited empirical evidence regarding the level of adoption and impacts of improved beekeeping technologies such as improved beehives, protective gears, smokers and honey extractor in Tanzania. With the exception of the study done by Nkojera (2010), other studies on the adoption of improved beekeeping technologies in Tanzania (Giliba *et al.,* 2010; Lietaer, 2009; Hausser and Mpuya, 2004; Mwakatobe, 2000) have relied on descriptive statistics without application of robust statistical models to compare the performance of adopters and non-adopters. Also, such studies have only applied single econometric model; hence they fail to account for counterfactual effects in estimating the level of impacts. Consequently, there is limited understanding of the statistical validity of the factors suggested to constrain adoption or provide incentives for adopting the improved beekeeping technologies. Against this background, this study focused on the adoption and income poverty impacts of using improved beehives among beekeepers in Tabora and Katavi regions using the propensity score matching technique and the endogenous switching treatment effect model which accounts for selection problems and unobservable factors.

5.2 Study Design, Sampling Procedures and Data Collection

Data used in this study was collected from a sample of 198 households in Katavi and Tabora regions. The two regions are found within the western miombo woodland in

Tanzania where majority of the rural communities depend on tobacco production as their main source of income. Beekeeping is also practiced in locations with abundant miombo woodlands which are found in Sikonge, Uyui, Urambo and Kaliua districts in Tabora region; and Mpanda, Mlele and Nsimbo districts in Katavi region. These miombo woodlands are particularly suitable for beekeeping as they provide excellent bee forage. According to Monela and Abdallah (2007) *Julbernadia globiflora*, and *Brachystegia spp* were the best nectar producing trees. Others were *Brachystegia spiciformis* and *Zanthoxylum chalybeum*. Also the presence of forage species such as *Dombeya burgessiae*, *Maesa lanceolata*, *Diospyros whyteana*, *Uapaca kirkiana*, *Vitex mombassae* and *Mysalicifolia spp* significantly supports the honey industry (Monela and Abdallah, 2007). During the first stage, in each region, districts were stratified according to their bee production levels, there-after three districts from Tabora region and one district from Katavi region were purposively selected to form the study area. A total sample of 198 households was randomly selected from the sampling frame of all beekeepers in the study area. A questionnaire was used to collect information from households through personal interviews. Data was collected on; farmers' patterns of resource use, technology choices, production of different bee products from traditional and improved beehives, inputs and outputs prices, socioeconomic profiles, access to extension and credit services; and access to trainings.

5.3 Conceptual Framework and Estimation Techniques

5.3.1 Adoption of technologies

In Tanzania, over 95% of the small scale beekeepers use log and bark hives (Laika and Machangu, 2008). These traditional hives are locally considered to be the most convenient because of the abundance of miombo woodlands providing easy access to these raw materials for producing bee hives. Improved beehives are another alternative technology available to beekeepers. Much effort has been made by various stakeholders to promote them. Nonetheless, only a small proportion of beekeepers are using improved beehives. These few adopters have responded to efforts by the government, non-government organizations (NGO's) and development projects to promote the improved beekeeping technology to be more technically efficiency and environmentally sensitive. In the context of this study improved beehives included transitional and commercial beehives. Transitional beehives comprised of the Tanzanian Top Bar hives and box hives. The langstroth hives are considered as commercial beehives.

According to Becerril and Abdulai (2010) and Crost *et al.* (2007) the decision to adopt technologies is modelled in the random utility framework. Let p^* represent the difference between the utility from adoption (U_{iA}) and the utility from non-adoption (U_{iNA}) of improved beehives such that household i will choose to adopt a technology if $P^* = U_{iA} - U_{iNA} > 0$. However, the two utility functions are unobservable and they can only be measured as a function of observable components in the latent variable model. This can be expressed as follows:

$$P_i^* = X_i\alpha + \varepsilon_i \text{ with } P_i = \begin{cases} 1 \;\; if \;\; P_i^* > 0 \\ 0 \;\; otherwise \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where P is a binary dummy variable for the use of improved hives; $P = 1$ if the technology is adopted and $P = 0$ otherwise; α = vectors of parameters to be estimated, X = a vector that represents household and farm level characteristics and ε = the random error term.

The adoption of improved beehives is assumed to increase productivity as well as household income accrued from beekeeping. If we assume our outcome variable of interest (household profit generated from beekeeping) is a linear function of a dummy variable for improved beehives use, along with a vector of other explanatory variables we define the relationship as presented in equation (2).

$$Y_i = \beta Z_i + \delta P_i + \mu_i \quad \text{……………………………………………………………….} \quad (2)$$

Where Y_i represents profit realized from beekeeping, P is an indicator variable for adoption as defined above, β and δ are vectors of parameters to be estimated, and μ is an error term. Thus the impact of adoption on the outcome variable is measured by estimation of the parameter δ. However, according to Faltermeier and Abdulai (2009) in order to estimate δ which is the accurate impact of technology adoption on outcome variables, farmers should be randomly assigned to adoption or non-adoption groups.

5.3.2 Impacts evaluation of improved beehive adoption

Contrary to experimental studies, in non-experimental studies we do not observe the outcome variables of household that adopt, had they not adopted. In experimental studies this problem is addressed by randomly assigning adoption to treatment and control groups, which assures that the outcome variables observed on the control households without adoption are statistically representative of what would have accrued without adoption. However, adoption is not randomly distributed to the two groups of households, but rather depends on the household itself deciding to adopt, given available information. The adopters and non-adopters may therefore be systematically different (Amare *et al.,* 2012).

Several studies on adoption of crop technologies (Hamazakaza *et al.,* 2013; Kalinda *et al.,* 2010; Langyintuo and Mungoma, 2008; Mason and Mofya-Mukuka, 2013; Mason and Smale, 2013) and a few on the beekeeping industry (Adgaba *et al.,* 2014; Nkojera, 2010; Wodajo, 2011; Mujuni *et al.,* 2012; Gorfu, 2005) have utilized single econometric models such as the correlated random effects (CRE), Tobit, double hurdle and other fixed-effect models. The disadvantage of using a single model is that the estimates are not robust enough to overcome the problem of counterfactual. This paper used two different econometric approaches; the endogenous switching regression (ESR) and propensity score matching (PSM) models to analyse the impact of using improved beehives in Tanzania.

5.3.2.1 Endogenous switching regression

The study intended to explore the impacts of adopting improve beehives on household profit realized from beekeeping as measured by the average treatment effect on the treated (ATT). The ATT computes the average difference in outcomes of adopters with and without the technology. Propensity Score Matching (PSM) is the mostly used method to calculate the ATT (Di Falco *et al.,* 2011). However, it ignores unobservable factors that affect the adoption process. The approach also assumes the coefficients (return) to independent variables to be the same for adopters and non-adopters, which has been found in many recent empirical analyses not to be the case (Asfaw *et al.,* 2012; Di Falco *et al.,* 2011; Shiferaw *et al.,* 2014; Teklewold *et al.,* 2013). Modelling the impacts of adopting improved beehives on the outcome variables under the endogenous switching regression (ESR) framework proceeds in two stages: The first stage is the decision to adopt improved beehives (equation 1), which is estimated using a probit model. In the second stage an Ordinary Least Squares (OLS) regression with selectivity correction is used to examine the relationship between the outcome variable and a set of explanatory variables conditional on the adoption decision. The two outcome regression equations, conditional on adoption can be expressed as:

Adopters: $y_{1i} = x_{1i}\beta_1 + w_{1i}$ if $P = 1$ .... (3a)

Non-adopters: $y_{2i} = x_{2i}\beta_2 + w_{2i}$ if $P = 0$ .... (3b)

Where x_{1i} and x_{2i} are vectors of exogenous covariates, β_1 and β_2 are vectors of parameters; and w_{1i} and w_{2i} are random disturbance terms. According to Shiferaw *et al.* (2014) for the ESR model to be identified it is important for the X variables in the adoption model to contain a selection instrument in addition to those automatically generated by the non-linearity of the selection adoption model. The selection instruments used were access to training on beekeeping practices, access to credit, and access to extension services. All these were coded as dummy variables. Selection of instruments was done after performing a simple falsification test. A variable was valid if it happened to affect the technology adoption process without affecting the outcome variable of interest. Results show that the selected instruments were valid as they were jointly statistically significant in explaining the adoption decision but were not statistically significant explaining the outcome equation.

The above ESR framework can be used to estimate the average treatment effect of the treated (ATT) and of the untreated (ATU) by comparing the expected values of the outcomes of adopters and non-adopters in actual and counterfactual scenarios. Following Di Falco *et al.* (2011) and Shiferaw *et al.* (2014) the ATT and ATU were calculated as follows:

Adopters (observed in the sample)

$$E(y_{i1} / P = 1; x) = x_{i1}\beta_1 + \sigma_{\varepsilon 1}\lambda_{i1} \quad \text{(4a)}$$

Non-adopters (observed in the sample)

$$E(y_{i2} / P = 0; x) = x_{i2}\beta_2 + \sigma_{\varepsilon 2}\lambda_{i2} \quad \text{(4b)}$$

Adopters had they decided not to adopt (counterfactual)

$$E(y_{i2} / P = 1; x) = x_{i1}\beta_2 + \sigma_{\varepsilon 2}\lambda_{i1} \quad \text{(4c)}$$

Non-adopters had they decided to adopt (counterfactual)

$$E(y_{i1}/P=0;x)=x_{i2}\beta_1+\sigma_{\varepsilon 1}\lambda_{i2} \quad \text{(4d)}$$

The average treatment effect on the treated (ATT) is computed as the difference between (4a) and (4c);

$$ATT=(y_{i1}/P=1;x)-(y_{i2}/P=1;x),$$

$$=x_{i1}(\beta_1-\beta_2)+\lambda_{i1}(\sigma_{\varepsilon 1}-\sigma_{\varepsilon 2}) \quad \text{(5)}$$

The average treatment effect on the untreated (ATU) is given by the difference between (4d) and (4b);

$$ATU=(y_{i1}/P=0;x)-(y_{i2}/P=0;x),$$

$$=x_{i2}(\beta_1-\beta_2)+\lambda_{i2}(\sigma_{\varepsilon 1}-\sigma_{\varepsilon 2}) \quad \text{(6)}$$

The expected change in the mean outcome of adopters if the adopters had similar characteristics to non-adopters or vice versa, are captured by the first term on the right of equations (5) and (6). The second term (λ) is the selection term that captures all potential effects of the difference in unobserved variables.

5.3.2.2 Propensity score matching

Since results from ESR may be sensitive to the model assumption such as selection of instrumental variables, the PSM approach was also used to check robustness of the estimated treatment effect results from ESR. According to Heckman *et al.* (1997), if Y_1 is the level of profit when the household i is subject to treatment ($P=1$) and Y_0 is the same variable when the household does not adopt improved beekeeping hives ($P=0$). Then, according to Takahashi and Barrett (2013) the ATT can be defined as:

$$ATT=E\{Y_1-Y_0/P=1\}=E(Y_1/P=1)-E(Y_0/P=1) \quad \text{(7)}$$

We can observe the outcome variable of adopters $(E(Y_1/P=1))$ but we cannot observe the outcome of those adopters had they not adopted $(E(Y_0/P=1))$. Hence, estimating the

ATT using Equation (7) may lead to biased estimates (Takahashi and Barrett, 2013). The PSM method relies on the assumption of conditional independence where, conditional on the probability of adoption, given observable covariates, Y_0 an outcome of interest in the absence of treatment and Y_1 the outcome of interest for adopters, P are statistically independent (Takahashi and Barrett, 2013). Rosenbaum and Rubin (1983) define the propensity score or probability of receiving treatment as:

$$p(X) = pr(P = 1)/X \quad \text{..} \quad (8)$$

Another important assumption of PSM is the common support condition, which requires substantial overlap in covariates between adopters and non-adopters, so that households being compared have a common probability of being both an adopter or a non-adopter, such that $0 < p(X) < 1$ (Takahashi and Barrett, 2013). If the two assumptions are met, then the PSM estimator for ATT can be specified as the mean difference of the adopters matched with non-adopters who are balanced on the propensity scores and fall within the region of common support for matching adopters with their non-adopters, expressed as:

$$ATT = E(Y_1 / P = 1, p(X) - E(Y_0 / P = 1, p(X)) \quad \text{..} \quad (9)$$

Estimating the PSM is a two-step procedure: First a probability (Logit or Probit) model for adoption of improved beekeeping hives is estimated to calculate the propensity score for each observation; second, each adopter is matched to a non-adopter with similar propensity score values. It is important to note that PSM tries to compare the difference between the outcome variables of adopters and non-adopters with similar characteristics; however, this method cannot correct for unobservable bias because it only controls for observed variables to the extent that they are measured perfectly.

5.4 Results and Discussion

5.4.1 Socioeconomic characteristics of the respondents

Table 5.1 shows descriptive statistics of different variables by region and adoption category of improved beekeeping hive. The results show that both adopters and non-adopters in the two regions had a mean age of around 50 years implying that majority of beekeepers are within the productive age category. On average both the adopters' and non-adopters' households supported 7 people per household. All respondents are characterized in terms of household characteristics such as education (number of schooling years), experience in beekeeping, productivity of beehives and annual profit from beekeeping. Education is hypothesized to have a positive impact on technology adoption. The level of education measured in the number of years of schooling was higher for adopters compared to non-adopters category in both regions; it ranged from 7 to 8 for adopters whereas for non-adopters it ranged from 5 to 6 years. Education enables adopters to understand better the importance of adopting improved beekeeping technologies. Adopters are distinguishable based on years of experience in beekeeping, adopters in Tabora region had less years of experience compared to their fellows in Katavi region.

Both in Tabora and Katavi regions, the productivity of improved beehive (litres of honey/hive) was higher than that of traditional beehive. However, among adopters the productivity of improved beehive differed; for instance adopters in Katavi region realized higher productivity (14.29 litres of honey/hive) than those in Tabora region (11.1litres of honey/hive). Similar trends of productivity among adopters were also observed in beeswax production. Even beekeeper who exclusively used traditional beehives (non-adopters of improved beehives) in Katavi region recorded higher productivity of honey (i.e. about 8.98 litres /hive) than their counterparts in Tabora region who recorded 6.91litres/hive. In both districts, adopters using improved beehives had less average annual income (profit) accruing from beekeeping than non-adopters. This finding conform with that of Kuboja *et al.* (2016) who reported a higher net farm income for beekeepers using traditional beehives compared to those who were using improved beehives (Table 5.1). However, it is worth realizing that such comparison was based on un-matched samples and there are reasons to doubt whether it leads to a balanced number of cases and controls across the levels of the selected matching variables. This comparison may wrongly be interpreted to mean no impact of adopting improved beehives on household’s profit levels. We reconcile this view through matched comparisons in section 5.4.3.1.

Table 5.1: Socioeconomic characteristics of the sample households by region and adoption status

Name of the region	Adoption category	Variables	n	Minimum	Maximum	Mean	Std. Deviation
Katavi	Non-adopter	Age of the household head	46	29.00	78.00	49.17	12.42
		Total number of household member (family size)	46	2.00	12.00	5.69	2.61
		Experience in beekeeping (years)	46	3	40	13.04	11.39
		Total number of traditional beehives owned	46	.00	500.00	58.72	102.25
		Productivity of traditional beehive (litres of honey/hive)	34	2.85	16.92	8.98	3.52
		Total profit from beekeeping (TZS)	46	0	8664750.00	1265648.10	2025955.30
		Number of years of schooling	46	.00	13.00	5.0870	4.16
	Adopter	Age of the household head	14	30.00	75.00	52.28	12.63
		Total number of household member (family size)	14	3.00	11.00	6.57	2.38
		Experience in beekeeping (years)	14	4	40	15.21	12.28
		Total number of improved beehives owned	14	4	500	59	131.88
		Productivity of improved beehives (litres of honey/hive)	14	5.70	20.00	14.29	5.55
		Total profit from beekeeping (TZS)	14	57 950.00	8523479.40	923802.80	2239728.40
		Number of years of schooling	14	6.00	11.00	7.36	1.22
Tabora	Non-adopter	Age of the household head	116	24.00	85.00	53.43	15.93
		Total number of household member (family size)	116	1.00	15.00	6.97	3.04
		Experience in beekeeping (years)	116	2	60	19.41	18.91
		Productivity of traditional beehive (litres of honey/hive)	62	.67	18.75	6.91	4.01
		Total profit from beekeeping (TZS)	116	0	6491032.00	657381.50	1366286.90
		Number of years of schooling	116	.00	14.00	6.6810	2.57614
	Adopter	Age of the household head	22	28.00	81.00	51.68	13.61
		Total number of household member (family size)	22	3.00	15.00	7.00	3.08
		Experience in beekeeping (years)	22	2	20	7.14	5.91
		Total number of improved beehives owned	22	2	160	33	42.48
		Productivity of improved beehive (litres of honey/hive)	22	3.00	20.00	11.10	5.25
		Total profit from beekeeping (TZS)	22	27 486.80	3255210.00	609742.20	771807.80
		Number of years of schooling	22	7.00	14.00	8.41	2.72

Out of 60 respondents in Katavi region 90% were male and 10% were female; whereas in Tabora region out of 138 respondents, 97.8% were male and only 2.2% were female. This result suggests that majority of beekeepers in both regions were male. Further analysis was conducted to assess the level of adoption of beekeeping technologies between male and female respondents. In Katavi region out of 46 respondents who were non-adopters; 10.9% were female and 89.1% were male. In the case of adopters; out of 14, only 7.1% were female while the remaining 92.9% were male. In Tabora, out of 116 non-adopters, 1.7% were female and rest were male. In the case of adopters; out of 22, 4.5% were female and 95.5% were male. These results suggest that in both regions male were more likely to adopt the technology compare to their counterpart female.

Adopters in both regions had more access to extension services, credit, training on beekeeping practices as well as on markets and marketing information than non-adopters. To assess if there was an association between each of these dummy variables with the adoption status the Pearson Chi-Square test was conducted to determine if the two variables under consideration were independent. Results are given in Table 5.2 indicating that access to extension services, credit, market and marketing information as well as training on improved beekeeping practices had a significant effect on adoption levels of improved beehives across the study area. We therefore reject the null hypothesis that the variables are independent of the adoption decision. The alternative hypothesis that the factors relate to the decision to adopt improved beehives is accepted.

Table 5.2: Chi-Square Tests statistics

Region	Variable	Chi-Square value	df	Asymp.Sig. (2-sided)
Tabora	Access to extension services (1=yes, 0=no)	35.768	1	0.000
	Access to credit (1=yes, 0=no)	25.148	1	0.000
	Access to market and marketing information (1=yes, 0=no)	15.552	1	0.000
	Access to training on beekeeping (1=yes, 0=no)	37.776	1	0.000
Katavi	Access to extension services (1=yes, 0=no)	22.319	1	0.000
	Access to credit (1=yes, 0=no)	29.814	1	0.000
	Access to market and marketing information (1=yes, 0=no)	8.673	1	0.003
	Access to training on beekeeping (1=yes, 0=no)	29.376	1	0.000

These variables are important for the adoption of improved beehives. Hence, institutional support services such as extension services and financial services are important in the dissemination of new technologies and consequently affect their impacts. It is worth noting, however, that the descriptive results are only indicative of the impacts of the technology in question. Thus, the empirical analysis that follows, aims at providing more formal and conclusive evidence of the adoption impacts of improved beehives in the miombo woodland of Tabora and Katavi region, western Tanzania.

5.4.2 Determinants of improved beehives adoption

To adopt or not to adopt a technology is often a discrete choice. Discrete choice econometric models have widely been used in estimating models that involve discrete economic decision-making processes (Guerrem and Moon, 2004). Using qualitative responses such as Tobit and Probit models is often recommended for adoption studies. According to Kipsat (2002) choosing a Probit choice model is sometimes rejected on the grounds that it leads to inefficient estimators and that the estimated probabilities are not constrained to assume either 0 or 1 as demanded by the probability theory. Meanwhile, the Probit specification has an advantage over the Logit model for small sample sizes (less than 1000). Thus, with a sample size of only 198 beekeepers, the present study employed a

Probit model to examine determinants of beekeepers' decision to use or not to use improved beehives. Initially explanatory variables fitted in the model were checked for multicollinearity. The test showed that there is no separate collinearity among the explanatory variables. There was however an association between access to extension services and contacts with extension officers; and between access to credit and use of credit in beekeeping. Looking into their contribution to the estimated model, contact with extension officers and use of credit in beekeeping were dropped from the analysis. Eventually the empirical Probit model used to estimate the adoption of improved beehives among beekeepers was specified as presented in equation 10.

$$y_i = \beta_0 + \beta_1 Age + \beta_2 Sex + \beta_3 Hhz + \beta_4 Credit + \beta_5 Train + \beta_6 Exp + \beta_7 Mkt + \beta_8 \mathrm{Re}g + \beta_9 Edu + \beta_{10} Ext \qquad (10)$$

Where y_i takes the value of one for adopters or zero for non-adopters, Age = age of the household head (years), Sex = sex of the household head ("1" male and "0" female), Hhz = household size, $Credit$ = access to credit ("1" access to credit and "0" otherwise), $Train$ = training on improved beekeeping practices ("1" access to training and "0" otherwise), Exp = experience in beekeeping (years), Mkt = access to market and marketing information ("1" access to market and "0" otherwise), $\mathrm{Re}g$ = region of residence of beekeepers ("1" Tabora and "0" Katavi), Edu = number of years of schooling, Ext = access to extension services ("1" access to extension services and "0" otherwise) and βs are coefficients.

Estimated parameters of the Probit model for improved beehives adoption are presented in Table 5.3. The goodness-of-fit measurements of the model are also given in Table 5.3. The likelihood ratio index confirms the influence of independent variables on adoption as 72%

of the total variation of the dependent variable attributes was accounted for by the independent variables. The coefficient for years of experience in beekeeping is negative (-0.07) and significant (p<0.01). The coefficient for region is also negative (-0.61) but not significant. The negative signs are interpreted to mean less likelihood of adoption. In the case of experience, as beekeepers get more experience they are less likely to adopt improved beehives.

Among coefficients that have a positive influence on adoption such as training on beekeeping (2.5), age of the household head (0.07) and access to extension services (1.64) were highly significant (p<0.01). This finding is in line with that of Adgaba *et al.* (2014) and Wodajo (2011) who found a positive and significant influence of education on adoption of improved beehives among beekeepers in the Kingdom of Saudi Arabia and Ethiopia, respectively. The results further showed that access to extension services increases the likelihood of adopting improved beehives. Beekeepers that are regularly visited by extension workers are likely to adopt improved beehives due to their increased exposure and awareness. Similar results were also found for the adoption of improved beehives in Mpanda district in Tanzania (Nkojera, 2010), Ethiopia (Gebremichael and Gebremedhin, 2014; Wodajo, 2010; Gorfu, 2005) and Bushenyi district in western Uganda (Mujuni *et al.*, 2012).

Access to credit (1.1) and the beekeeper's number of years of schooling (0.24) were also highly significant (p<0.05). Training develops skills and knowledge among beekeepers whereas access to credit improved their investment capacity. This result confirms similar findings by Wodajo (2011) and Nkojera (2010) who found a positive significant influence of training on adoption of improved beehives in Ethiopia and Tanzania, respectively. The positive influence on access to credit was also reported by Mujuni *et al.* (2012) in Uganda and Wodajo (2011) in Ethiopia. Increased access to institutional support services such as extension, credit, skills and knowledge should thus be a major part of efforts for promoting adoption of improved beekeeping technologies.

The remaining variables including; sex of the household head, household size, access to market and marketing information had a positive effect on adoption but their coefficients were not significant (Table 5.3). Easy access to and availability of marketing information plays a major role of reducing high transaction costs to beekeepers in the search of markets for their products as well as inputs such as honey extractors, smokers and protective gears. Thus, if beekeepers have access to markets and marketing information, then their likelihood of adopting the improved beehives is higher than non-adopters. Similar result was also reported by Gebremichael and Gebremedhin (2014) who found a significant influence of market access on the adoption of improved beekeeping hives in northern Ethiopia.

Table 5.3: Probit estimates of the determinants of adoption of improved beehives in western Tanzania

Variables	**Coefficient**	**Std. Error**	**z**	$p > \|z\|$
Age of the household head	0.07	0.02	2.97	0.003
Sex of the household head	0.86	0.97	0.88	0.38
Household size	0.10	0.08	1.29	0.19
Access to credit	1.10	0.49	2.22	0.03
Training on beekeeping	2.50	0.57	4.37	0.00
Experience in beekeeping	-0.07	0.02	-3.14	0.002
Access to market and marketing information	0.69	0.43	1.61	0.10
Region	-0.61	0.48	-1.25	0.21
Number of years of schooling	0.24	0.10	2.35	0.02
Access to extension services	1.64	0.47	3.49	0.00
Constant	-9.61	2.51	-3.83	0.00
Summary statistics				
Log likelihood	-25.87			
Pseudo R^2	0.72			
Prob > Chi^2	0.00			
LR Chi^2 (10)	132.58			
Number of observation	197			

5.4.3 Impacts of improved beehives on household income

The relationship between adoption of improved beehives and annual profit from beekeeping as an outcome variable is theoretically complex (Amare *et al.*, 2012). Taking into account these complexities in impact evaluation; this study estimated the impact of improved beehives on annual household income in terms of profit realized from beekeeping using both propensity score matching (PSM) and endogenous switching regression (ESR). The use of PSM requires a choice of matching algorithm to be used. However, according to Caliendo and Kopeinig (2008) all matching algorithms have their own drawbacks. In small samples a choice of the matching algorithm is important to ensure comparison of only exact matches. Thus, based on the data set of this study, where we had a larger number of untreated compared to treated; the nearest neighbour (NNM) and kernel matching algorithms were used to match treated units with similar representatives within the untreated sample. The nearest neighbour matching algorithm was used as it gives good quality matching as well as reduces bias since it matches with replacement; whereas the kernel matching method allows more information to be used for constructing counterfactual outcome as it uses weighted averages of all individuals in the control group.

5.4.3.1 Propensity score matching results

Prior to estimating the impacts of the treatment on the treated, a graphical prediction of whether there is a treatment effect or not was done by plotting the outcome variable against the propensity scores for the treatment and control groups separately. The treatment and the control groups overlapped yet they were clearly distinct from each other; implying that the treatment has an impact as the common support assumption was graphically verified. The PSM estimated using both the nearest neighbour and kernel matching algorithms are presented in Table 5.4.

Table 5.4: PSM estimates of the impact of improved beehives adoption on annual household beekeeping income

Matching algorithm	variable	Sample	Treated	Control	Difference	S.E	*t-stat*
NNM	Annual beekeeping profit	Unmatched	750 151.0	830 099.2	-79 948.2	295 388.5	-0.3
		ATT	750 151.0	214 522.5	535 628.5	301 927.0	1.8
Kernel	Annul beekeeping profit	Unmatched	750 151.0	830 099.2	-79 948.2	295 388.5	-0.3
		ATT	900 801.3	285 343.8	615 457.5	813 602.9	0.8

Results show that regardless of the matching algorithm used in PSM estimation, adoption of improved beehives help to increase beekeepers' annual profit from beekeeping. Using the Nearest Neighbour Matching (NNM) and Kernel matching the average treatment effects on the treated was 535 628.50TZS and 615 457.50TZS, respectively. A Similar finding was also reported by Affognon *et al.* (2015) in Kenya where adoption of modern hives improved honey production.

5.4.3.2 Endogenous switching regression results

Since results of the PSM model may be biased due to unobservable factors, the ESR model was also used to check the robustness of the estimated effects obtained from the PSM model. Table 5.5 presents the ESR-based average treatment effects of adopting improved beehives on annual average household income from beekeeping under actual and counterfactual conditions. The predicted outcome variable from ESR is used to examine the impact of improved beehives by the adoption category. The model is also used to validate PSM results regarding impact assessment of the improved beehives. The ESR-based average treatment effect estimates presented in Table 5. 5 are similar to the PSM-based estimates.

Table 5.5: ESR estimates of the impact of improved beehives adoption on annual household beekeeping income

Matching alogarithm	variable	Sample	Treated	Control	Difference	S.E	*t-stat*
	Annual	Unmatched	750 151.0	830 099.2	-79 948.2	295 388.5	-0.3
NNM	beekeeping	ATT	750 151.0	214 522.5	535 628.5	301 927.0	1.8
	profit	ATU	830 099.2	374 567.9	-455 531.2	-	-
	Annual	Unmatched	750 151.0	830 099.2	-79 948.2	295 388.5	-0.3
Kernel	beekeeping	ATT	900 801.3	285 343.8	615 457.5	813 602.9	0.8
	profit	ATU	839 019.3	509 416.1	-329 603.2	-	-

The results also show that adoption of improved beehives increases annual household beekeeping income; adopters would benefit more compared to non-adopters. The average increment on annual profit from beekeeping for adopters (ATT) is 535 628.50 TZS equivalent to US$246.8 when matching was done using the nearest neighbour matching algorithm. In the case of the kernel matching method the average treatment effects on the treated is 615 457.50 TZS equivalent to US$283.6. This implies that adopters would realise less profit from beekeeping had they not adopted improved beehives. Results from both models (PSM and ESR) have similar findings and implications. The average treatment effect on the untreated (ATU) results from ESR also indicate that non-adopters would have achieved beekeeping income gains of 455 531.20 TZS equivalent to US$ 168.7 or 329 603.20TZS equivalent to US$ 151.9 per year had they adopted improved beehives depending on the matching algorithm used.

5.5 Conclusion

This paper analyses the determinants and impacts of adoption of improved beehives on households' annual profit from beekeeping in western part of Tanzania using data obtained from a sample of 198 beekeeper households. The probit model estimates of the determinants of adoption of improved beekeeping hives showed that adoption of improved beekeeping hives is significantly related to the age of the household head, years of formal schooling, access to credit, access to extension services, training and experience in beekeeping. This implies that easy access to institutional support such as extension services, financial services and capacity building would play an important role in promoting adoption of improved beekeeping technology leading to reduced income poverty.

Using propensity score matching and endogenous switching regression models, the paper further shows that adoption of improved beekeeping hives leads to significant gains in beekeeping annual profit. The magnitudes of the estimated effects were almost similar across the two econometric methods. In view of these findings there is a need for policies and strategies aimed at enhancing the adoption of improved beehives among non-adopters. This can be achieved through more efficient extension services, credit facilitation, training and market access and marketing information systems.

CHAPTER SIX

6.0 HONEYBEE COLONIES ABSCONDING IN TANZANIA: UNDERLYING FACTORS AND ITS FINANCIAL IMPLICATIONS

[1]Nicholaus Musimu Kuboja, [2]Isinika, A.C. and [3]Kilima, F.T.M.

[1]Ministry of Agriculture livestock and Fisheries, Tumbi Agricultural Research Institute, P.O. Box 306, Tabora, Tanzania.

[2]Sokoine University of Agriculture, Institute of Continuing Education (ICE), P.O. Box 3044, Chuo Kikuu, Morogoro, Tanzania.

[3]Sokoine University of Agriculture, School of Agricultural Economics and Business Studies, P.O. Box 3007, Chuo Kikuu, Morogoro, Tanzania.

Abstract

An assessment was conducted to investigate honeybee colonies absconding and its financial implication among beekeepers in Tabora and Katavi regions, Western Tanzania. Four districts were selected on the basis of adoption of improved beehives. A total of 198 beekeepers were randomly selected for household interviews. Questionnaire-based data were supplemented with data from focus group discussions and interviews with key informants who included experienced beekeepers, extension workers and bee experts. Drought, presence of bee pests, diseases and predators and shortage of bee forage were identified as major factors causing honeybee colonies to abscond their hives in the study area. The act of honeybee colonies absconding among beekeepers within the sample caused an average annual income loss of TZS 2 894 555.89 (US$ 1822.5) and TZS 1 797 105.02 (US$ 1131.5) among beekeepers using traditional and those using improved beehives, respectively. Based on these findings, the study recommends: developing best practices for pests, diseases and predators control; improving main road infrastructure;

enhancing bee forage through establishment of water bodies close to apiary sites; proper harvesting of bee products; and formation of beekeepers' cooperatives to facilitate collective marketing, access to information and credit services.

Key words: *Drought, bee forage, absconding, bee pests and predators, financial loss.*

6.1 INTRODUCTION

In Tanzania, there is a wide range of vegetation that is suitable for beekeeping. Mainland Tanzania has about 33.5 million hectares of forests and woodlands that are ideal for beekeeping industry (Marjo and Feek, 2010; Songo, 2015). Almost 20.5 and 13 million hectares of this area comprise of unreserved and reserved forests woodlands, respectively. More than 80 000 hectares of the gazetted forest reserves consist of forest plantations that are also suitable for beekeeping. The mangrove forests of Mainland Tanzania that cover about 115 500 hectares are also valuable as bee forage (Mustalahti and Lund, 2010). Agricultural land is another potential area for beekeeping where substantial bee products can be produced using flowers from agricultural crops such as sunflower, green beans, coffee, sisal and coconut (Omari, 2010).

The presence of both stinging and non-stinging honeybees, coupled with the existence of indigenous knowledge in beekeeping to enhance honey production. In 2003 the contribution of the beekeeping sub-sector to the Gross Domestic Product (GDP) in Tanzania was only 1% (MNRT, 2004). Despite such low contribution to the national GDP, the sector is a source of income to most of rural people in miombo woodlands (MNRT, 2001). In urban areas, most of the people who are engaged in the beekeeping sector are employed in processing, trading and exporting bee products. In 2004/2005 Tanzania exported 367.72 tons of honey and 193 tons of beeswax worth US$ 418 358 and US$ 754 400, respectively (Mapolu, 2005). Most of these products are produced by small scale beekeepers using traditional technologies, accounting for more than 95% of the honey and nearly all the beeswax produced in Tanzania. Such production and income can be increased by minimizing losses due to pests, predators, diseases and bee colonies absconding their hives due to various reasons.

Tanzania is estimated to have around 9.2 million honeybee colonies whose production potential is about 138,000 tons of honey and 9,200 tons of beeswax per annum (URT, 2012). Based on the average prices for the year 2011 (US $ 8 per kg of honey and US $ 16 per kg of beeswax) the products are worth US $ 8,832 million and US $ 147.2 million, respectively. Currently, Tanzania produces approximately 9,000 tons of honey worth TZS 27 billion and 600 tons of beeswax worth TZS 3 billion. However, this level of production is equivalent to only 6.5% of the potential (URT, 2013). The prevailing low production of bee products in Tanzania is associated with shortage of bee forage, presence of pests and predators, low adoption of improved beekeeping technologies, inadequate supply of beekeeping facilities and unreliable market along with poor access to extension services (Kihwele, 1985; Backeus and Ruffo, 2010; Namwata *et al.,* 2013; Igunda; 2013; Kimaro *et al.,* 2013; Minja and Nkumilwa, 2016).

The shortage of bee forage is increasingly recognized as problem; it has been attributed to drought and deforestation, mostly arising from shifting cultivation, expanding settlements, improper timber harvesting and use of traditional beekeeping practices (Kimaro *et al.,* 2013). Within miombo woodlands, deforestation is an outcome of tree debarking and tree cutting for making bark and log hives, respectively. Most of the trees which are cut are indigenous trees, which take longer time (at least 25 years) to reach maturity (Sileshi *et al.,* 2007). Use of fire to harvest bee products is another traditional practice that accelerates deforestation in the miombo woodlands. In contrast, improved beekeeping practices contribute to conserving the natural environment and are perceived to be environmentally friendly. Such practices include use of wood by-products for making hives. The by-products are obtained from trees which are harvested according to recommended forest management plans. Other improved beekeeping practices that are environmental friendly include use of smokers and protective gears during harvesting. Improved beekeeping also plays a vital role in the socioeconomic development of beekeeping communities; and is considered to be one of the most important rural economic activities for sustainable development in poor countries such as Tanzania.

Honeybee colonies' absconding their hives is another common challenge among beekeepers that threaten sustainable beekeeping. Absconding is defined as the act of a colony which forms a swarm abandoning a hive and presumably re-establishes itself elsewhere. When the colonies move, no bee category (worker, adult or viable immature queens) is left behind in the hive. Absconding can occur either due to disturbance or it may be induced by resource scarcity. Disturbance induced absconding mostly results from partial or total disturbance of colonies by predators, destruction of honey comb by pests or rain entering into the hives. Disturbance may also be due to poor harvesting techniques, which involve leaving hives on the ground as beekeepers are trying to escape from stinging bees. Meanwhile, resources induced absconding results from shortage of bee forage and water, which in tropical habitats occurs during the dry season. At such periods there is relatively little flowering, hence reducing food supply for bees for prolonged periods; ultimately forcing honeybee colonies to move to other areas with better forage and water (Pradeepa and Bhat, 2014).

Worldwide, the act of honeybee colonies absconding their hives has been noted as a threat to the beekeeping sub-sector. Major underlying factors for absconding include: shortage of bee forage, incidences of diseases, drought, pests and predators (Schäfer *et al.*, 2010: Mahmood *et al.*, 2012; Pirk *et al.*, 2014; Pradeepa and Bhat, 2014; Yirga *et al.*, 2014; Begna, 2015; Strauss *et al.*, 2015). Elsewhere, absconding has caused a significant loss of colonies and income. For instance in South Africa, Pirk *et al.* (2014) reported a total loss of 29.6% colonies in 2009/2010.The loss increased to 46.2% in 2010/2011. In India, a survey on the prevalence of absconding honeybee colonies in the traditional beekeeping sub-sector reported losses ranging from 37.66% to 54.81% (Pradeepa and Bhat, 2014). A similar study in Ethiopia reported monetary loss among beekeepers using traditional practices amounting to 72.9% of the expected income due to absconding. The corresponding figure for improved practices was 33.9% (Yirga *et al.*, 2014).

The problem of absconding has also been reported to be severe in the beekeeping sector in Tanzania (Kihwele, 1985). However, little is known about its magnitude and the underlying factors. Little is also known about the financial implication among beekeepers using improved and those using traditional beehives. This study was undertaken to investigate the nature of the problem, factors underlying the problem of absconding and its financial implication among beekeepers in Tabora and Katavi Regions, Western Tanzania.

6.2 METHODOLOGY

6.2.1 Study area, sampling techniques and sample size

The study was conducted in Tabora and Katavi Regions, which are located in the Western part of Tanzania within the miombo woodlands. These woodlands have a high potential for sustainable beekeeping owing to their large area which accommodates a wide range of bee forage. The study focused on four districts out of eleven within the western miombo woodlands; three from Tabora Region (Kaliua, Urambo and Sikonge) and one from Katavi Region (Mlele). These districts have a higher proportion of beekeepers who have adopted improved beehives, which is good for comparing the performance of the two technologies. Moreover, the government and NGOs have been promoting improved beehives in these districts hence allowing the comparison between the two technologies. A total of 198 beekeepers were randomly selected. Out of these, only 36 (18.2%) were using improved beehives while the rest were using traditional beehives.

6.2.2 Conceptual framework of the study

Existing information reveals that, for some farmers, beekeeping is an important portfolio among their economic activities. Such farmers are expected to behave as rational economic agents as they allocate resources for beekeeping in order to maximize profit, which they achieve by producing the highest value of bee products at the least cost. Any beekeeper incurs fixed and variable costs. Fixed costs are associated with acquiring the hives while variable costs are related to labour for installing the hives and follow up inspection. Once the hives are acquired and hanged, the beekeeper should strive to maximize profit by minimizing loss of bee products and honeybee colonies.

Quantities of honey and beeswax that are harvested during a particular season are a function of; yield per hive, the proportion of hives that were occupied by bees and management practices of hives. A beekeeper therefore suffers profit loss if yield per hive and the proportion of occupied hives are small. The loss could also be a result of poor management. The loss from absconding bee colonies can be significantly high if most of the hives are not occupied. Under these circumstances a rational beekeeper, is expected to adopt beekeeping technology that minimizes loss of bee products and the problem of absconding. Information on absconding and related problem was collected from beekeepers and key informants in the study area as described in the next section.

6.2.3 Data collection and analysis

Data were collected from beekeepers using a structured questionnaire. The data included; the number of hives owned by a beekeeper, the quantity of honey and beeswax produced during 2013, honey and beeswax prices prevailing at the time of data collection, constraints as well as challenges to beekeeping. Data from households were supplemented by information from personal observations, focus group discussions and interviews with key informants who included selected beekeepers, beekeeping extension agents and bee experts at the Tanzania Wildlife Research Institute (TAWIRI).

Data from the household questionnaire were coded, entered and analysed using SPSS computer software. Descriptive statistics such as frequency, means, range and standard deviations were used to identify the relative importance of constraints facing beekeepers as well as their proposed solutions. Data from interviews with key informants and focus group discussion were summarized thematically to highlight common aspects about pests, diseases and predators; and how the beekeepers control them using indigenous knowledge. The quantity of honey and beeswax lost due to honeybee colonies absconding was calculated, and the value was computed using prevailing market prices.

6.3 RESULTS AND DISCUSSION

Within the study area there are two periods for harvesting bee products. The peak harvesting period takes place from June to August when the largest quantity of honey is collected. This honey is also of higher quality due to better food availability during the rainy season. The second period runs from October to December. To understand the problem of absconding it was also important to get a general view about other issues related to beekeeping.

6.3.1 Sources of honeybee colonies

During focus group discussions and interviews with key informants it was noted that beekeepers had different means to get honeybee colonies. The first and most common means was known as “*let alone*” technique which involved hanging beehives on tree and waiting for the colony to enter. The second approach involved catching colonies that were found at temporary sites such as bees found hanging on a tree in the forest as they move from one place to another. Beekeepers used locally made swarm catchers to catch such colonies. Some beekeepers however inherited honeybee colonies from their parents.

6.3.2 Apiary sites

About 52.8% of the beekeepers using traditional and 47.6% of those using improved beehives in Katavi Region kept their bees in their backyards. In contrast, in Tabora Region, the majority (83.7%) of beekeepers using traditional and 87% of those using improved beehives kept their bees in forest reserves. This difference in the location imply that beekeepers in Katavi Region were more likely to have better access to their beehives for inspection and cleaning since their apiary sites were closer to home. It would therefore be expected that beehives located close to residence would produce more honey per hive compared to those located deep in forest reserves. This argument is supported by the findings from this study as presented in Table 6.1. The mean yield of honey per improved beehive hanged in the backyard was 15.39 litres/hive compared to 10.71 litres per improved beehive hanged in the forest reserves. Similarly, traditional beehive hanged in the backyard had a mean honey yield of 7.98 litres compared to 6.49 litres per hive hanged in forest and both differences between the two at each apiary site were statistically significant at $p<0.005$ (Table 6.1).

Table 6.1: Descriptive statistics for comparison of honey yield (litres/hive) by location of hives

Types of hives	Apiary sites	n	Mean	Min	Max	Std. Deviation	t	df	Sig. (2-tailled)
Improved	Backyard	11	15.39	6	20	5.54	2.37	29	0.02
	Forest reserves	20	10.71	3	20	5.11			
Traditional	Backyard	32	7.98	2.85	11	2.46	2.16	103	0.03
	Forest reserves	53	6.49	0.67	18.75	3.99			

Other apiary sites identified in Katavi region were in Mlele game controlled area, forest reserves, Mlele beekeeping zones and at community forests within villages. In Tabora region other apiary sites were community forest and in backyards. However, both apiary sites faced common constraints.

6.3.3 Beekeeping constraints

Prioritization was done to identify the most important constraints that hindered development of beekeeping in the study area. Table 6.2 shows the percentage of respondents listing various constraints they faced. For the sample as a whole poor road infrastructures ranks highest being mentioned by 17.2% of all the respondents. Across traditional and improved beehives users this problem was mentioned by 17.5% and 13.3% respectively. Unreliable markets ranked second being mentioned by 14.1% of all the respondents. However, unreliable markets was ranked second after poor roads infrastructure among traditional beehives users, but for those who used improved beehives unreliable market ranked fourth (Table 6.2). The difference in ranking this problem in the overall sample is probably because users of improved beehives had more contact with extension agents and other beekeeping stakeholders who supported them to adopt the technology, and they were likely to avail them with marketing information. Third in overall ranking are shortage of bee forage (13.6%) and inadequate supply of beekeeping facilities (13.6%). Pests, predators and diseases come in fourth (12.6%) followed by inadequate capital (10%), theft (5.1%), wild fire (4%) and others as listed in Table 6.2. Among improved beehives users shortage of bee forage featured as a very important constraint for the majority who kept their bees in their backyards. At the backyards bees are likely to face more shortage of bee forage compared to bees deep in forest reserves where there is a great diversity of plant species with varying drought tolerance.

Similar constraints affecting beekeepers in Katavi and Tabora as well as between those using traditional and those using improved beehives were reported. Shortage of bee forage was listed as the most important problem in Katavi Region, both under improved and traditional beehives users. This accounted for 20% of the responses from beekeepers using improved beehives and 17% from beekeepers using traditional hives. This problem also accounted a large proportion (16.4%) of the responses of beekeepers using improved beehives in Tabora compared to those used traditional beehives. Only 11.7% of beekeepers using traditional beehives mentioned shortage of bee forage as one of the constraint. This problem came fourth after poor road infrastructure (18%), followed by poor supply of honey processing facilities (14.3%) and unreliable markets (13.9%). Unreliable markets also ranked highest among users of traditional beehives in Katavi (17%). Poor road infrastructure to apiary was the second most important problem among users of traditional beehives in Katavi Region. Similar findings have been reported in Ethiopia and South Africa (Beyene and Verschuur, 2014; Pirk *et al.*, 2014; Yirga *et al.*, 2012; Abebe and Puskur, 2011; Workneh and Ranjitha, 2011). These studies reported drought, honeybee pests, diseases and predators, shortage of bee forage, shortage of beekeeping facilities, poor infrastructures and poor marketing as the main problem hindering growth of the beekeeping subsector.

Table 6.2: Beekeeping constraints

Constraints of beekeeping	Katavi		Tabora		Category of beehive users				Overall Sample Total (n=198)	
	Improved hive (%)	Traditional hives (%)	Improved hive (%)	Traditional hive (%)	Improved hive (n=36)		Traditional hive (n=162)			
					%	Rank	%	Rank	%	Rank
Shortage of bee forage	20	17	16.4	11.6	17.8	1	13.1	4	13.6	3
Presence of pests, diseases and predators	17.1	15.2	12.7	10.9	14.4	2	12.1	5	12.6	4
Inadequate labour forces	8.6	4.5	-	1.4	3.3	7	2.2	11	3	8
Poor infrastructure (roads to the apiary sites)	17.1	16.1	10.9	18	13.3	3	17.5	1	17.2	1
Unreliable markets	11.4	17	12.7	13.9	12.2	4	14.8	2	14.1	2
Inadequate supply of beekeeping facilities	11.4	11.6	14.5	14.3	13.3	3	13.5	3	13.6	3
Theft	8.6	4.5	7.3	5.1	7.8	6	4.9	7	5.1	6
Wild fires	-	1.8	5.5	5.4	3.3	7	4.4	8	4	7
Encroachment by Livestock	2.9	1.8	3.6	3.4	3.3	7	3.0	10	3	8
Restricted entry in the conserved areas	-	1.8	3.6	3.7	2.2	8	3.2	9	3	8
Inadequate capital and poor access to credit	2.9	8.9	12.7	12.2	8.9	5	11.3	6	10	5

It should be noted that most of the traditional beehives are sited deep in the miombo woodlands where road access is poor. The woodland in Tabora, is found mostly within the Ugalla watershed where perennial inundated grasslands and water sources are abundant (Hazelhurst and Milner, 2007). Thus, it is not likely that bees would to face the problem of bee forage shortage. This may be the reason why the problem of forage came fourth among users of traditional beehives in Tabora. While the problem of absconding was not mentioned at all. Some of the underlying factors leading to absconding have already been discussed earlier (section 6.1) and they have significant financial implications.

6.3.4 Honeybee colonies absconding and its financial implications

According to findings presented in Table 6.3 for the sample as a whole about 84.8% of the respondents experienced the problem of absconding; being slightly higher among users of traditional beehives (85.8%) who reported the problem compared to 80.6% of improved beehive users. This is probably because, for improved beehives, it is easy to open the hive for inspection and clean, which reduces attacks from pests, diseases as well as predators. Among traditional beehive users the problem was more severe in Katavi (93.5%) than in Tabora (82.8%).

Table 6.3: Honeybee colonies absconding from hives

Response on whether beekeeper had experienced absconding of honeybee colonies	Katavi		Tabora		Category of beehive users		Overall sample total (n=198)
	Improved hives (%) (n=14)	Traditional hives (%) (n=46)	Improved hives (%) (n=22)	Traditional hives (%) (n=116)	Improved hives (%) (n=36	Traditional hives (%) (n=162)	
Yes	64.3	93.5	68.2	82.8	80.6	85.8	84.5
No	35.7	6.5	31.8	17.2	19.4	14.2	15.2

The underlying reasons for absconding reported by the respondents were almost similar across beekeepers (Table 6. 4).

Table 6.4: Reasons for honeybee colonies absconding from hives

Reasons for absconding	Katavi		Tabora		Category of beehive users				Overall sample total (n=198)	
	Improved hive (%)	Traditional hive (%)	Improved hive (%)	Traditional hive (%)	Improved hive (n=36)		Traditional hive (n=162)			
					%	Rank	%	Rank	%	Rank
Drought	56.5	51.9	47.2	57.3	50.8	1	55.4	1	54.5	1
Pests, diseases & predators	26.1	26.6	25	18.2	25.4	2	21.2	2	21.7	2
Shortage of bee forage	17.4	16.5	22.2	20.3	20.3	3	18.9	3	19.2	3
Wild fires	-	1.3	5.6	2.1	3.4	4	1.8	5	2.5	4
Inappropriate harvesting practices	-	3.8	-	2.1		-	2.7	4	2	5

The three factors identified to be major factors underlying the absconding of honey bee colonies in their descending order of importance were: drought; presence of pests, diseases and predators; and shortage of bee forage. Also, about three percent and two percent of the responses by beekeepers using improved beehives and traditional hives identified wildfire to be one of the reasons for absconding, respectively. Occurrence of wild fire was mentioned by 5.6% of users of improved beehives in Tabora as well as 1.3% and 2.1% of traditional beehive users in Katavi and Tabora, respectively. The higher rate among improved beehive users may be attributed to their apiary sites. Most of them kept their hives at their backyards and within community forests which are more prone to wild fire than hives located deep in the forest reserves.

Inappropriate harvesting methods were also reported to cause the problem of absconding. Inappropriate harvesting methods involved complete removal of the honey comb, leaving nothing as feeds for bees. In some occasions beehives were left on the ground after harvesting, which attracted pests and predators to the hive. Both actions may lead honeybee colonies to move out due to inadequate food supply. Similar findings were reported in Ethiopia (Abebe and Puskur, 2011; Workneh, 2007; Kebede and Lemma, 2007) and the Kingdom of Saudi Arabia (Adgaba *et al.*, 2014).

Major pests and predators identified for causing absconding of honeybee colonies include ants, birds, spiders, wax moth, beetle, bee lice, honey badger, cat worms and lizards. Beekeepers used different indigenous methods to overcome these problems including; application of ash, tying a rope around the entrance of hives which is locally referred to as hanging the predator’s neck. Other traditional methods included application of dirty engine oil on the outer sides of hives, physical killing the pests and improving sanitation around hives.

6.3.4.1 Income losses due to absconding

Further analysis was conducted to assess the financial loss arising from absconding of honeybees from improved and traditional hives. Table 6.5 shows the annual average income loss due to honeybee colonies absconding.

Table 6.5: Annual average income loss due to honeybee colony absconding

Variables	Types of beehive	
	Traditional beehives	**Improved beehives**
Average number beehives owned per household (a)	103	45
Average number of beehives harvested per household (b)	25	12
Average number beehives honeybee colony absconding per household (c)	78	33
Average yield of beehive (litres of honey/beehive) (d)	7.59	12.38
Average yield of beehive (kg of beeswax/beehive) (e)	1.41	1.16
Output price (TZS/litre of honey) (f)	3,859.30	3,871.60
Output price (TZS/kg of beeswax) (g)	5,544.40	5,627.00
Expected average annual total income per household (TZS) (h) = (a*d*f)+(a*e*g)	3,822,298.17	2,450,597.76
Actual average annual income obtained per household (TZS) (i) = (b*d*f)+(b*e*g)	927,742.28	653,492.74
Average annual income loss per household (TZS) (j) = (h-i)	2,894,555.89	1,797,105.02
Annual percentage income loss per household (%) = (j/h) * 100	75.7	73.3

From the total of 103 traditional hives and 45 improved beehives, it would be possible to earn TZS 3 822 298.17 (US$ 2406.7) and TZS 2 450 597.76 (US$ 1543) per household per annum from the sale of honey and beeswax. The actual annual income generated using traditional beehives was TZS 927 742.28 (US$ 584.2) per household and TZS 653 492.74 (US$ 411.5) per household from improved beehives, whereas the annual income loss due to absconding was up to TZS 2 894 555.89 (US$ 1822.5) and 1 797 105.02 (US$ 1131.5) for traditional and improved beehives, respectively (Table 6.5). Based on these findings, beekeepers under both technologies were realising only about a quarter (25% – 27%) of their potential income from beekeeping. If the factors underlying the problem of absconding were addressed, beekeepers would tripe their income from this source, thereby contributing to poverty reduction and livelihood improvement.

6.5. Conclusion and Recommendations

The analysis in this study has revealed that drought; presence of bee pests, diseases and predators as well as shortage of bee forage are the main factors underlying the problem of honeybee colonies absconding in the study area. The findings also reveal a significant income loss from absconding. The loss was higher among beekeepers using traditional hives than those using improved hives. In order to reduce such losses, several recommendations are made. First, beekeepers should be trained on improved management practices of beehives in order to minimize the problem of absconding. The emphasis should also be on promoting use of improved beehives among beekeepers since using traditional beehives tends to cause higher losses of revenues due to honeybee colonies absconding and related problems. Second, efforts should be made to improve road infrastructure and water facilities around apiary sites. Improvement of road infrastructure will minimize transport costs, hence increasing profit. Third, to address problems related to market access and low product prices, it is recommended that beekeepers should be encouraged to form or join cooperatives in order to facilitate collective marketing and access to information as well as credit.

CHAPTER SEVEN

7.0 MAJOR CONCLUSIONS, POLICY IMPLICATIONS AND RECOMMENDATIONS

7.1 Conclusion and Policy Implications

The overall objective of the study was to evaluate the profitability, efficiency and adoption of improved beehives and its implications on household income among beekeepers in Tabora and Katavi regions of Tanzania. Based on the findings, the study concludes that majority of small-scale beekeepers are still using traditional beekeeping technologies such as log beehives, fire for harvesting, local honey extraction methods as well as indigenous methods for pests, diseases and predators control. Productivity of improved beehives was higher compared to that of traditional beehives. However, the higher productivity of improved beehives was associated with low net return due to higher operational costs and lack of price premium to value products realized from improved beehives. Small scale beekeepers were found to be economically efficient, with a mean efficiency of 91.7%. This indicates that despite their level of efficiency, there is enormous room for beekeepers to increase profit using the same technology and through optimum allocation of resources. Results further suggest that regular contact with the beekeeping extension officers and access to trainings on improved beekeeping practices are likely to improve the economic efficiency of beekeepers.

However, adoption of improved beehives in the study area was only about 18%. Age of the household head, years of formal schooling, access to credits, access to extension services, training and experience in beekeeping were found to significantly influencing the adoption rate. Although adoption of improved beehives was still low, its impacts on annual households' profit realized from beekeeping was higher among adopters compared to non-adopters based on the more robust PSM and ESR analytical methods. This is in contrast to the simpler profitability analysis which showed that higher profit level for non-adopters. Despite the benefits realized, beekeepers were facing several constraints. Shortage of bee forage, poor infrastructures, presence of bee pests, diseases and predators, lack of reliable markets, lack of capital and beekeeping facilities were the major constraints affecting the honey sub sector in the study area. Also, absconding of honeybee colonies was a threat as it caused big annual financial losses among beekeepers.

7.2 Recommendations

Based on these findings, the study draws the following recommendations;

7.2.1 Enhancing profitability and adoption of improved beehives among beekeepers

In order to maximize profit accrued from beekeeping and adoption of improved beehives the study recommends;

i) There is a need to develop a marketing system that value and r pays a premium for the good quality bee products realized from using improved beehives. Where feasible, beekeepers could be organized and supported to undertake collective action through cooperatives for example, to participate and compete fairly in the market place. Other means to make their products unique and more appealing to buyers are worth pursuing. These could be pioneered by relevant institutions including Local Government Authorities (LGAs) and NGOs in respective areas.

ii) Among other factors, the lower net income from improved beehive was associated with high investment cost and shorter economic life spans of improved beehives both leading to high operating costs. The implication of these results is that technologies that increase the life span of the improved beehives are likely to improve the profitability leading to increased adoption. There is a need for construction of improved beehives with a longer economic life span. The current improved beehives have economic life span of at most 4 years against 7 years of the log beehives (traditional) especially when they are hanged in forestry.

7.2.2 Policy strategies for efficiency improvement among beekeepers

Based on the findings that socioeconomic characteristics of beekeepers were one of the sources of inefficiency study recommends:

i.) Improved access to institutional support such as extension services and capacity building. Thus, regular and timely provision of extension services and beekeeping training among beekeepers can improve their practices. Government efforts should be directed at providing education, improving extension services, promoting social change and support in order to improve the extent to which beekeepers are technically and allocatively efficient.

7.2.3 To enhance sustainable beekeeping in the miombo woodlands

The study established that:

i.) Beekeepers should be supported with beekeeping facilities such as improved beehives, honey press, protective gears and smokers. To ensure ready availabilities of these facilities among small scale beekeepers the government through their local government authorities should have sustainable means of accessing these facilities among beekeepers; this can be done by provision of financial support.

ii.) Extension services for beekeeping, Research services provides and NGOs should enhance research and extension activities on honeybee colonies absconding management, bee forage, developing affordable technology from locally available materials, promotion of ant protection methods and organizing apiary demonstration.

7.3 Contribution of the Study to Knowledge

In the miombo woodland of Tabora and Katavi regions there are several indigenous knowledge and beekeeping practices which are used by most of beekeepers. Such practices include that of catching the swarm, making traditional hives, knowledge about controlling pests, diseases and predator control. These practices can be adapted for improving further modern beekeeping activities which are currently being adopted at a low rate by beekeepers in the study area. Such indigenous knowledge could play a significant role for developing beekeeping and for sustaing beekeeping activities in the miombo woodland of Tanzania where the use of modern technologies remains low.

Use of propensity score matching and endogenous switching regression models enabled estimation of not only the direction of change of the target outcome variable but provided robust estimation of the magnitude of change. Consequently, comparison through descriptive statistics or routine inferential statistics can potentially lead to inference about the superiority of the traditional over improved technology in beekeeping.

7.4 Areas for Further Research

The study is further suggesting other areas for research. These include:

i.) To investigate the economic implications of using traditional and improved beehives on environmental conservation

ii.) To characterize honey bees and major pests, diseases and predators of economic importance in the miombo woodlands

iii.) To investigate indigenous knowledge and its relevance for sustainable beekeeping in the miombo woodland of Tanzania

iv.) To investigate biological causes of honeybee colonies absconding from hives

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APPENDICES

Appendix 1: Household Survey questionnaire

1.0 GENERAL INFORMATION

1.1 Interviewer's name…………………………………………………………..................

1.2 Date for interview…………………………………………………………………………

1.3 Respondent's identification number…………………………………………………

1.4 Questionnaire Number (QID No)……………………………………………………

1.5 Village Name…………………………………………………………………………...

1.6 Ward Name……………………………………………………………………………..

1.7 District Name (Please tick whichever applies)

1) Urambo [ ]
2) Kaliua [ ]
3) Sikonge [ ]
4) Mlele [ ]

1.8 Region Name (Please tick whichever applies)

1) Tabora [ ]
2) Katavi [ ]

2.0 RESPONDENT'S CHARACTERISTICS AND HOUSEHOLD BACKGROUND INFORMATION

2.1 Age of the respondent ………………. (years)

2.2 Age of the household head [___]

2.3 Gender of the household head: Male [ ] Female [ ]

2.4 Education level of the respondent (please tick whichever applies)

1. Non formal education [ ]

2. Primary education [ ]
3. Secondary education [ ]
4. Tertiary/college/or university [ ]

2.5 Total number of household members (family size) ……………………………………

2.6 Total number of household members by sex: Males [ ], Female [ ]

2.7 Total number of household members who were full involved in beekeeping................

2.8 What is your main occupation? …………………………………………………………

2.9 Did you have access to extension services for beekeeping in the last year 2013?

1) Yes
2) No

2.10 If yes, in 2.6 above, how frequently were you visited by the extension officer during the last year 2013[ ]

2.11 If the answer in question (2.6) is **YES**, indicate where did you get extension services?

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

2.12 Did you accessed credit for beekeeping in the year 2013?

1) Yes 2) No

2.13 If **yes**, in (2.12) what proportion of the credit/loan was used in bee production [%]

2.14 Do you belong to any beekeeping association?

1) Yes 2) No

2.15 If the answer in question (2.9) is **YES**, what is the name of your association do you belong? ……………………………………………………………………

2.16 For the past five years, have you ever attended any training on beekeeping?

1) Yes 2) No

2.17 If the answer in question (2.16) is **YES**, from whom did you receive trainings?

1) ……………………………………………………………………………………….

2) ……………………………………………………………………………………….

3.0 BEEKEEPING PRACTICES

3.1 Did you work as an individual or you belonged to a certain association?

1) As an individual 2) As an association

3.2 If you worked as an association, which association did you belong?

……………………………………………………………………………………………

…………………………………………………………………………………………

3.3 If you worked alone/individual where did you get your labour force?

1) Hired labour 2) Family labour 3) Contract labour

3.4 How long have you been in beekeeping? …………….. (years)

3.5 What was your initial investment cash in the beekeeping enterprise? …………. (TZS)

3.6 Did you use your own beehives?

1) Yes 2) No

3.7 If the answer in question (3.6) is **No**, from whom did you borrow?

……………………………………………………………………………………………

……………………………………………………………………………………………

3.8 What type of beehives did you use?

1) Traditional bee hives 2) Improved bee hives 3) Both traditional and improved bee hives 4) Any other (please specify)_____________

3.9 If you used improved beehives, what type of improved beehives did you use?

…………………………………………………………………………………………

………………..…………………………………………………………………………

…………………………………………………………………………………………

3.10 How did you get the improved beehives?

1) Purchase 2) Give on credit from beekeeping association 3) Supplied by beekeeping companies/NGOs 4) Own construction

3.11 If purchased, how much TZS did it cost for one beehive? ………………………….

3.12 How many improved beehives did you have in the last year 2013? ………………..

3.13 How many bee colonies did you have in the year 2013? ....

3.14 What was the average number of top bar frames per beehive? ……………………..

3.15 What is the size (cubic volume) of your beehive? ………………………………......

3.16 How many traditional beehives did you have? ……………………………………..

3.17 Was there any member at your household who was engaging (own bee hives) in beekeeping?

1) Yes 2) No

3.18 If **yes** how many in your household were involved in beekeeping in the year 2013

……………………………………………………………………………………...

3.19 Where did you hang your beehives?

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………….

3.20 What was the approximated distance from your homestead to places where you hanged your beehives? ………………………………….……………………… (km)

3.21 Beekeeping management practices

Codes	**Beekeeping management practices**	**Scores [1,0]**	
[1]	Did you undertake beehive inspection?	1	0
[2]	Did you use smoke during harvesting?	1	0
[3]	Did you wear protective gears during harvesting?	1	0
[4]	Did you use fire during harvesting?	0	1
[5]	Did you have a beekeeping calendar?	1	0
[6]	Did you use honey press to extract honey from cobs?	1	0
[7]	After extraction of honey did you need/not need to filter it?	0	1
[8]	It is recommended to harvest all the cobs from the beehive	0	1
[9]	It is recommended to harvest both honey and propils at ago	0	1
[10]	Did you take initiatives to control pests and diseases?	1	0
[11]	Did you feed bees in beehives during dry season?	1	0
[12]	Did you note the first day when bees enter into beehives?	1	0
[13]	Sometimes did you use fire (boiling) to extract honey from cobs?	0	1
[14]	Any utensil was used to store honey	0	1
[15]	During harvesting you can combine both honey combs without and with bees, provided you will use honey press and filter the extract	0	1
	Total scores		

Note: yes = 1; no = 0

3.22 How many times did you undertake beehive inspection per month in the year 2013? ....

3.23 Did you use protective gear during honey harvesting for the year 2013?

1) Yes [__] 2) No [__]

3.24 If No, in 3.23 above, how did you protect yourself from bee stinging during harvesting?

…………………………………………………………………………………………

…………………………………………………………………………………………

3.25 Did you use honey press to extract honey from combs?

1) Yes [ ] 2) No [ ]

3.26 If No, in 3.25 above, what did you use to extract honey from combs?

………………………………………………………………………………………….

………………………………………………………………………………………….

3.27 How did you know when honey was ready for harvesting?

…………………………………………………………………………………………

………………………………………………………………………………………...

3.28 What did/do you consider as the biggest problems in beekeeping (rank in terms of importance/threat)?

1) ………………………………………………………………………………

2) ………………………………………………………………………………

4.0 BEE PRODUCTS AND THEIR MARKETING

4.1 In 2013 season how many beehives did you harvest? ………………………………….

4.2 How many litres of honey did you harvest per beehive per season (2013)? ………….

4.3 How many litres of honey did you harvest this season (2013) ?……………………...

4.4 What was your annual saving from beekeeping? ………………………………… (TZS)

4.5 Where did you sell your honey for the 2013 season?

1) Local market [__] 2) Urban market [__] 3) Regional market [__] 4) International market [__] 5) Other specify [________]

4.6 How much did you sell per litre? ………………………………………….. (TZS)

4.7 Did you collect beeswax in this season (2013)?

1) Yes 2) No

4.8 How much did you collect per bee hive? ………………………………………. (kg)

4.9 How much did you collect per season (2013)? …………………………………... (kg)

4.10 Did you sell beeswax during the 2013 season?

1) Yes 2) No

4.11 If **yes** how much did you sell per kg of beeswax? …………………………. (TZS)

4.12 If you didn't sell beeswax, what did you do with it?

…………………………………………………………………………………………

………………………………………………………………………………………

4.13 What other bee products did you harvest during the 2013 season?

…………………………………………………………………………………………

……………………………………………………………………………………..

4.14 How much of each product did you harvest per season (2013)?

Sno.	**Other bee products**	**Amount harvested per season (2013)**	**Unit prices (TZS)**

4.15 How many harvesting seasons did you have in the last year 2013? ………………

4.16 Has the price of honey increased or decreased since 2005?

1) Increased 2) Decreased

5.0 CONTRIBUTION OF BEEKEEPING ON HOUSEHOLD INCOME IN RELATION WITH OTHER LIVELIHOOD ACTIVITIES

5.1 What were the sources of your household income in the year 2013? (rank in matter of importance/contribution to household livelihood)

1) Farming [_] 2) Livestock keeping [_] 3) Beekeeping [_] 4) Petty trade [_] 5) Others (specify) [______]

5.2 What was the annual contribution of each source on household income? Fill the table

Source of income		**Quantity produced (unit)**	**Unit price**	**Total income (TZS)**
Code	**Agriculture crops**			
	Tobacco			
	Groundnuts			
	Cassava			
	Maize			
	Rice			
Others				
Livestock				
	Cows			
	Goats			
	Sheep			
	Pig			
.	Chicken			
Nonfarm Sources				
.	Lumbering			

.	Public/civil employment			
.	Petty trade			
Others specify				

5.3 What was your estimated annual income (Tick √)

1) Below 600,000TZS 2) Between 600,000 – 2,500,000TZS

3) Above 2,500,000TZS

5.4 As a beekeeper, give details regarding on beekeeping enterprise for the year 2013

Variables	**Using improved beehives**		**Using traditional**	
Bees' products	**quantity**	**unit**	**Quantity**	**unit**
Honey (liters')				
Beeswax (Kg)				
Propils				
Pollen				
Bees' products unit price				
Honey (TZS)				
Beeswax (TZS)				
Propils (TZS)				
Pollen (TZS)				
Gross revenue				
Variable costs incurred	**Costs (TZS)**			
Beehive construction				
Honey harvesting				

Honey processing				
Transport harvested honey				
Hiving beehives				
Other specify				
Total variable cost				

6.0 CLIMATIC AND ENVIRONMENTAL FACTORS INFLUENCING HONEY PRODUCTION

6.1 What do you consider as climatic factors influencing honey production in your area?

……………………………………………………………………………………………

……………………………………………………………………………………………

6.2 What are the most important environmental factors influencing bee production in this area?

……………………………………………………………………………………………

……………………………………………………………………………………………

6.3 For the past ten years did you experience drought in your area?

1) Yes 2) No

6.4 For the past ten years did you experience flooding in your area?

1) Yes 2) No

6.5 Do you experience seasonal migration of bees?

1) Yes 2) No

6.6 If there was migration what do you think were the causes of the migration? [This might be an intervene point or change in weather]

……………………………………………………………………………………………

……………………………………………………………………………………………

Appendix 2: Focus Group Discussion guideline questions

1. For sustainable beekeeping production what do you think are appropriate practices to be adopted by beekeepers?
2. What practices is majority using in your locality and why?
3. What do you consider as benefits accrued from beekeeping?
4. Do you have any challenges or constraints in beekeeping?
5. What are major constraints in beekeeping?
6. Do you have any indigenous or improve methods for addressing beekeeping constraints and challenges?
7. What available indigenous control methods used to combat major challenges in beekeeping?
8. What available improved control methods used to combat major challenges in beekeeping?
9. In your community/locality what are the major sources of honeybee colonies?
10. Give your suggests on how maximizing the use of improved beekeeping technologies among small-scale beekeepers