ECONOMIC EFFICIENCY OF SMALLHOLDER RICE PRODUCERS IN MARAMVYA IRRIGATED SCHEME, BURUNDI

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL AND APPLIED ECONOMICS OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

This study assessed the extent to which rice producers from Maramvya irrigated scheme could raise their productivity and profitability if they efficiently use inputs in producing rice. To achieve this objective, simple random sampling was used to select 230 rice farmers in the study area and cross-sectional data were collected for season 2016/A. The collected data were subjected to analysis where output responsiveness with respect to each of the inputs, technical, allocative and economic efficiencies were estimated. Stochastic frontier analysis was used to estimate technical, allocative and economic efficiencies. The study applied Cobb-Douglas functional form for the stochastic frontier production and cost functions and used one-step maximum likelihood estimation to estimate parameters for stochastic frontier models. The study further assessed factors affecting efficiency levels among rice producers. Findings of this study reveal that output elasticities with respect to land, labour, seed and fertilizer were 0.41, 0.45, -0.11 and 0.24 respectively, meaning that labour variable was more responsible in rice production increase while seed variable was in negative relationship with production levels. The mean technical, allocative and economic efficiencies were 82%, 71% and 58% respectively, meaning that the sampled farmers were relatively technically efficient than they were allocatively and economically, with 42% room to expand productivity and profitability. Furthermore, the results show that the major factor affecting efficiency levels positively in the study area was the level of education while age of the farmer, household size, access to credit and shortage of water significantly impact efficiency levels negatively. The study recommended introduction of new techniques rather than relying on expansion of land and labour intensification. Focus should be on input market and availability, but also in the long run, focus should be oriented on education and maintenance of canal for irrigation.

DECLARATION

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

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The above declaration is confirmed by;

Dr. Daniel Wilson Ndyetabula Date

(Supervisor)

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DEDICATION

This dissertation is dedicated to my beloved wife Sandrine Niyongabire and my sons Sammy Gaddiel Niteka and Guil Kaniel Mukundwa for their sincere love and patience while I was away from home.

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LIST OF ABBREVIATIONS

ADISCO	Appui au Développent Intégral et à la Solidarité des Collines (Support for Integral Development and Solidarity of Hill Sides)
AE	Allocative Efficiency
AERC	African Economic Research Consortium
BIF	Burundi International Franc
CSLP	Cadre Stratégique de Croissance et de Lutte Contre la Pauvreté (Framework for Economic Growth and Poverty Reduction)
DEA	Data Envelopment Analysis
EAC	East African Community
EE	Economic Efficiency
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GoB	Government of Burundi
ha	Hectare
ISTEEBU	Institut des Statistiques et d'Etudes Economiques du Burundi (Institute of Statistics and Economic Studies of Burundi)
LR	Likelihood Ratio
MLE	Maximum Likelihood Estimation
MVP	Margianl Value of the Physical Product
OLS	Ordinary Least Squares
PNDR-B	Stratégie Nationale de Développement du Secteur Rizicole (National Strategy for Development of Rice Sector)
PNIA	Programme National d'Investissement Agricole (National Program for

	Agricultural Investment)
PNSA	Programme National pour la Sécurité Alimentaire (National Program for Food Security)
RTS	Return to Scale
SFA	Stochastic Frontier Approach
SRA	Simple Regression Analysis
SRDI	Société pour le Développement de la Région de l’Imbo (Imbo Regional Development Society)
TE	Technical Efficiency
USADF	United States African Development Foundation

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Agriculture is the backbone of the economy of Burundi. For instance with a Gross Domestic Product (GDP) of 4 206.2 billion of BIF for year 2014, the contribution of the agriculture was estimated at 30%, employed more than 90% of total population and earned Burundi more than 50% of foreign currency (ISTEEBU, 2015; Central Bank of Burundi, 2014). The main contribution of agricultural sector to the GDP is from cash crops while food crops display a decreasing trend (Central Bank of Burundi, 2014). For example, food crops' contribution to GDP was estimated at 8.4% in 2013 which declined to 1.4% in 2014 (Central Bank of Burundi, 2014).

Within the category of food crops, cereals are important (ISTEEBU, 2015) and in terms of volume, rice ranks second cereal produced after maize (GoB, 2016). Rice is mostly produced under three types of agricultural systems: upland system in country side, lowland rainfed system in southern Imbo and Moso and lowland irrigated system in central Imbo (ISTEEBU, 2015). Importance of rice is undeniable, but due to lack of details in the National Agricultural Account and data inconsistence, it is not easy to quantify the exact contribution of rice to the economy. For example based on year 2011 data, the value of total rice produced was estimated at 75 billion of BIF (GoB, 2014), that is 16% of GDP. But reports for following years whether from ISTEEBU, GoB or Central Bank of Burundi do not systematically give details on the evolutionary trend on how rice subsector contributes to GDP.

Rice has become a point of interest because it offers a number of advantages (include easy storage, well adapted to hydromorphic land during rainfall season and high potential demand) compared to other crops (GoB, 2014). The National Agricultural Strategy 2008-2015 has therefore identified it as a strategic crop for success and self-sufficiency in food security and import substitution.

Given its importance with regard to both poverty and food security, rice is at the center of key strategic roadmap documents for agricultural development namely, Strategic Framework for Economic Growth and Poverty Reduction (SFEGPR), National Agricultural Strategy 2008 – 2015 (NAS), National Program for Food Security 2009 – 2015 (NPFS), National Program for Agricultural Investment 2012-2017 (NPAI) and finally National Strategy for Development of Rice Sector 2014 (NSDRS-B). The latter being focused specifically on rice sector had four objectives namely improvement of rice productivity, reduction of rice imports, amelioration of rice farmers' revenue and exportation of rice surplus (GoB, 2014).

1.2 Problem Statement

Burundi's production level for irrigated rice is low if we compare to yields in other African countries for irrigated rice which range from 3.5 to 7 tonnes/ha (FAO, 2016). The productivity is actually estimated at 4 tonnes per hectare (ISTEEBU, 2015) but irrigated ecosystems provide potentials for high yields because of better control of water. The Government of Burundi and non-government stakeholders are actively investing in rice production improvement, the motivation being the desire to combat food insecurity and turning rice into cash crop (GoB, 2008). Among other factors, increase in rice production is actually due to technological improvement such as adoption of new and improved varieties but mostly, expansion of total area cultivated (WARDA, 2007), for instance development of new schemes for the case of Burundi, explains much the increase in rice production.

Interventions made to increase rice productivity have basically focused on agronomic practices while efficient use of inputs in producing rice as a source of increased productivity and profitability have been less surveyed (Ndayitwayeko and Korir, 2012). Rice producers in Maramvya irrigated scheme would benefit from additional information on efficient production in order to enhance the profitability of their rice farming activity.

Recently, rice has turned into the main staple food for Burundi's population due to rapid urbanization, refugee repatriation and high quantity demanded by boarding schools, army and police (ADISCO, 2012). There is therefore a potential demand for rice due change in consumption pattern especially in urban areas (ADISCO, 2012). This potential demand in rice is presented as an opportunity for rice producers. Nonetheless, this advantage can only be exploited if rice farmers produce efficiently.

Finally, with a population density of 329 inhabitants/km^2 in arable land area, it is unlikely to develop new schemes in Burundi. Chances to increase rice production by bringing more land to rice cultivation are reduced. The only alternative achievable, not only on the short run view, but also because it is cheaper, is the efficient use of existing means of production. It is therefore through efficient production where farmers can enhance productivity and profitability by tracking opportunities offered by rice industry.

Systematic literature review done in this study shows little evidence on the existence of research on Economic Efficiency (EE) for Burundi rice sub-sector, that is an analysis that combines both Technical Efficiency (TE) and Allocative Efficiency (AE). An attempt by

Ndayitwayeko and Korir (2012) focused on TE living a gap on AE for understanding the overall EE on rice sub-sector in Burundi because as highlighted by Mubarak and Byerlee (1991), changes in the technical environment are often accompanied by changes in the economic environment. As such, a complete EE analysis would fill the gap and contribute to explore the potentials offered by rice industry through improved productivity and profitability. It is against this background that the current study was undertaken to analyze both technical and allocative efficiency to establish broader understanding of economic efficiency of rice smallholders in Burundi.

1.3 Objectives

1.3.1 Overall objective

The overall objective of this study is to analyze the EE and to identify factors that determine efficiency levels among smallholder rice producers in Maramvya irrigated scheme in Burundi.

1.3.2 Specific objectives

More specifically this study intends:

(i) To estimate elasticities of mean output with respect to each of the inputs used;

(ii) To estimate technical, allocative and economic efficiencies and

(iii) To determine factors influencing efficiency levels among smallholder rice producers in Maramvya irrigated scheme.

1.3.3 Hypotheses

(i) There is no statistically significant difference in responsiveness of output with respect to the level of inputs used for rice production in Maramvya irrigated scheme;

(ii) Rice farmers in Maramvya irrigated scheme are economically efficient;

(iii) The farmer specific characteristics and socio-economic factors do not affect efficiency levels for rice production in Maramvya irrigated scheme.

1.4 Significance of the Study

This study helps to understand whether smallholder rice producers in Maramvya irrigated scheme are producing efficiently or not with a view of informing rice producers, government and any stakeholder in rice production process. Hence, by estimating elasticities of mean output with respect to each input, the study will contribute to providing quantified information on the effect of changes in input use on the level of rice production. This information is important since rice farmers are concerned with key inputs that are more responsible for the increase in rice productivity. In this case, rice farmers will be aware of the extent to which the production can be affected subsequent to change in any input use other factors being held constant.

Having noted that efficiency studies in Burundi are very few with limited attention on technical efficiency, economic efficiency analysis will therefore fill the gap and contribute to exploration of the potentials offered by rice industry through ameliorated productivity and profitability.

Lastly, by identifying and understanding social economic characteristics that influence efficiency levels, the study will provide informative knowledge for producers, government and rice production stakeholders on key factors to focus on for their interventions in order to boost rice productivity. The study will contribute therefore to enlighten the policy makers toward exploiting efficiently the potentials offered by the rice sub-sector.

1.5 Limitation of the Study

This study has limitation at two levels: (i) biases due to review of efficiency theory and methodological selection and (ii) disentangling all types of inefficiencies.

Firstly, systematic review done for this study shown that research on efficiency measurement is experiencing resurgence in the number of methodological and applied works in recent decades to the extent that a comprehensive review of the overall literature on efficiency measurements would require another whole work (Daraio and Simar, 2007). In this study, the author gives an overview of efficiency measurements with a synthesized general taxonomy, the focus being on Stochastic Frontier Analysis (SFA). SFA is selected due to its advantages compared to other approaches with regards to problem under study. Therefore review of efficiency measurements in this study could be biased against nonparametric approaches, due to its focus on the parametric methods that is SFA.

Secondly, from the potential level of production, it is possible to distinguish different kind of inefficiencies rather than technical and allocative. Among others, inefficiencies can be scale inefficiency (technology restriction that is constant or non-constant return to scale), structural inefficiency (how an industry keeps up with its performance of best practice) (van Dijk *et al.*, 2016) and inefficiency due to motivation, information, monitoring, and agency problems within the firm, the so called “X-inefficiency” by Leibenstein (1966). Effort to capture inefficiency is not always successful as, typically, the estimated inefficiency component represents a small fraction of the overall residual variation (Sarafidis, 2002), meaning that EE can be of small magnitude within the whole inefficiency level. Therefore EE analysis cannot pretend to be a full analysis of all types of inefficiency in rice production. Further comprehensive studies are needed to disentangle all types of inefficiencies with a view of reducing the bound on production and profitability efficiency in rice production.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

This chapter presents the literature review on efficiency theory, efficiency measurement techniques and recent studies on efficiency in rice production. There is wide empirical research on efficiency of farmers in both developed and developing countries (Obwona, 2006). The spectacular widespread of efficiency studies is motivated by the advantages of efficiency analysis in improving agricultural productivity. Hence the analysis of existing literature on the theory of efficiency is a crucial step such that a comprehensive review of the overall literature would require another whole work (Daraio and Simar, 2007).

Under this chapter, the researcher gives an overview of efficiency theory and efficiency measurement techniques with a synthesized general taxonomy, the focus being on SFA. The focus on SFA is due to its advantages compared to other approaches.

2.2 Theoretical Literature

2.2.1 Efficiency theory

This study is based on the theory of efficiency which has a long and rich literature dating back to 1950s (Obwona, 2006; Ndayitwayeko and Korir, 2012). The break through in measuring efficiency using SFA is the work by Farrel (1957) that has brought the possibility of estimating theoretical ideal frontier functions previously defined by Koopmans (1951) and Debreu (1951) in their effort to bridge the gap between theory and empirical work. According to Farrel's (1957) argument, the reason for failure of efficiency measures is founded in the fact that the theoretical part underlying efficiency measurement has been ignored.

Due to the significant contribution by Farrel (1957), improvements have been made on efficiency measurement such that for the first time, technical and allocative efficiencies are measured within an empirical framework. The approach was later on ameliorated by Aigner *et al.* (1977), Meeusen and Van den Broeck (1977) by developing a stochastic production frontier where output of a firm is a function of a set of inputs, inefficiency, and random error. This development by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) is now the standard form for the parametric approach of economic efficiency analysis (Greene, 2008).

2.2.2 Efficiency measurement techniques

There are two approaches to efficiency measurement, which are parametric and nonparametric approaches. The two approaches can be compared with respect to the following criteria (Daraio and Simar, 2007):

(i) The specification of the functional form for the frontier (production/cost) function;

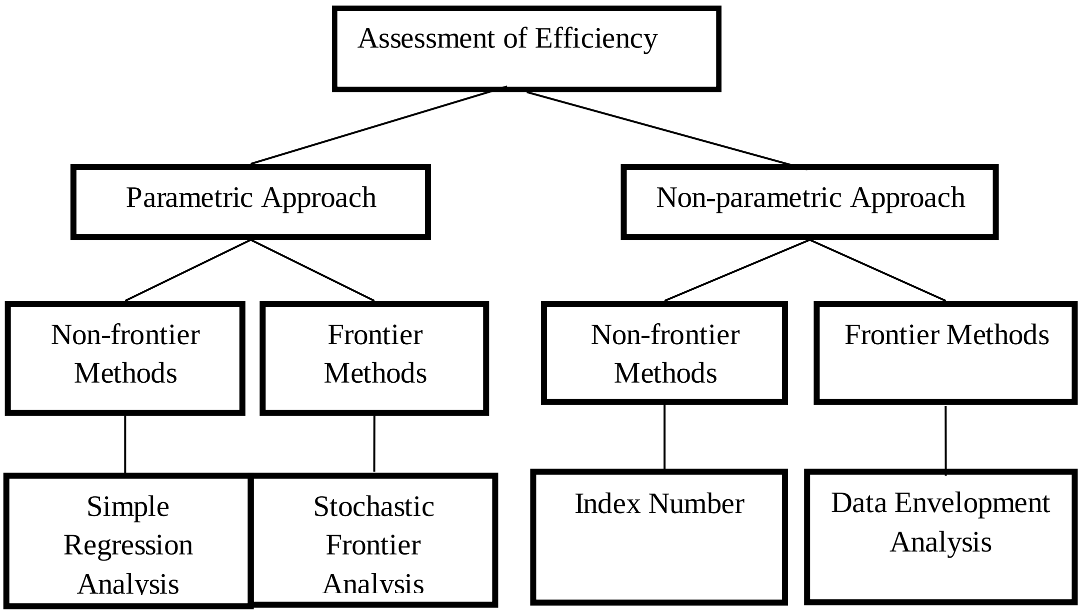
(ii) The presence of noise in the sample data and

(iii) The type of data analyzed.

The first criterion holds for parametric approach because the approach is based on the estimation of a theoretical frontier function where the output produced is a function of inputs factors, socio-economic characteristics of the farm. The main advantages of the fulfillment of this criterion are the economic interpretation of parameters and the statistical properties of estimators. The critical point of the criterion is how to specify an appropriate functional form with regard to the production process under study, because as highlighted by many authors (Leibenstein, 1966; Stigler, 1976; Coelli *et al*., 2005), misspecification can be a source of distortions on efficiency levels among farmers.

The second criterion holds also for parametric approach since econometric estimation allows random error on the estimation of the frontier. This is a weakness for the nonparametric approach for which any deviation from the frontier is considered to be an inefficiency and which is highly sensitive to super-efficient outliers and the key issue to handle when estimating is the identification of noise from inefficiency (Daraio and Simar, 2007; Villano, 2015; van Dijk, 2016).

The third criterion refers to the type of data used for the study (panel, time series, cross-sectional data) which may not fit to the approach used.



Sources: Sarafidis (2002).

Figure 1: Taxonomy of efficiency measurement techniques

From Figure 1, there are four techniques of efficiency measurement: Simple Regression Analysis (SRA) and Stochastic Frontier Analysis (SFA) for parametric approach and Index Number and Data Envelopment Analysis (DEA) for non-parametric approach.

The SRA involve the use of Ordinary Least Squares (OLS) in estimating statistical relationships between variables of production/cost functions thereby measuring relative efficiency within a sample of farmers. It involves minimization of the sum of the squared (vertical) deviations of actual observations from the fitted line (predicted production/cost level). Although the use of OLS is computationally easy and straightforward, it has serious limitations such as theoretical specification of production/cost function, lack of degree of freedom (difference between available observations and number of potential explanatory factors), problems of multicollinearity, measurement error, omission of variables and independency of residuals (Sarafidis, 2002).

While SFA and SRA are both parametric approaches, SFA is different from SRA for a number of factors. For instance while SRA uses OLS to find the best fitting line, SFA uses maximum likelihood estimation (MLE) principles to estimate the frontier for a given sample of observations. Furthermore, whereas SRA does not separate error from inefficiency, SFA allows separation of inefficiency from error components (Sarafidis, 2002). In principle, SFA uses available sample data to estimate a frontier for all observed sample individuals. This research uses SFA to estimate EE.

Index number and DEA are non-parametric approaches and relies on mathematical programming, rather than econometric techniques. Index number is a simple method to estimate efficiency non-parametrically across firms by constructing a simple index of relative performance (Sarafidis, 2002). By this index number derivation, DEA is introduced and can be well explained as procedure that uses mathematical linear programming techniques in order to find a set of weights for each firm in the sample that maximizes its efficiency score, subject to constraints that none of the firms has an efficiency score greater than 100 percent at those weights.

2.2.3 Advantages of stochastic frontier analysis

The advantage of SFA lies in its ability to apply econometric procedures that allow estimation of a theoretical production/cost function (frontier) including a stochastic component in the error term (Battese and Coelli, 1996). Basing the frontier analysis framework on econometric estimation is very important since representations of the potential production level, the boundary of the input requirement and efficiency scores in the input and output space are unknown (Daraio and Simar, 2007). The econometric problem to be solved by SFA is thus how to estimate these measures from a random sample of farmers. The technique allows therefore random shocks on the production function which is important since agriculture production is characterized by a number of uncontrollable factors like weather, fires, diseases, rainfall, drought, pests and other impediments to agricultural production process.

Furthermore, the insertion of the stochastic component into the frontier function enables researcher to measure efficiency level and by the same time determine the factors influencing efficiency of the farmer. Being an econometric approach, the technique has also an advantage of permitting statistical tests of hypothesizes (Coelli *et al.*, 2005) and finally, as the production function is specified, the technique allows measuring the responsiveness of output with respect to each of the inputs (elasticities), other things remaining constant.

2.3 Empirical Review on Efficiency in Rice Production

There is a large empirical literature on SFA in rice production. For instance, Magreta *et al.* (2013) employed the SFA to evaluate TE, AE and EE of rice production and also explored the factors that influence the efficiency levels of the rice farmers in Nkhate irrigated scheme in Malawi. The study used trans-log stochastic production frontier to analyze technical efficiency and used also tarns-log cost function to analyze the economic efficiency. The study revealed that farmers have a rice yield potential of 35% to be exploited and farmers could raise their profitability by 47% by adjusting input use. It has also been found that soil fertility status, access to credit, household size and farmers experience were the factors that influence the efficiency levels.

Ouedraogo (2015) conducted a study on economic efficiency on the irrigated land of Bagre in Burkina Faso applying SFA. He had an objective of assessing the potentials for increase rice production and identifying the determinants of efficiency that needed to be boosted. The results indicated that there is a potential to be exploited if farmers combine inputs in an efficient manner. Factors like mineral fertilizer, improved seed and capital were identified to improve economic efficiency if properly used by rice farmers.

Hye-Jung Kang and Yu Yu Tun (2015) analyzed the factors affecting rice production efficiency in Myanmar. They had an objective of obtaining a better understanding of the current rice production conditions in Myanmar through efficiency analysis, especially to examine the impact of mechanization on Myanmar rice production. They used both DEA and SFA with variable return to scale. The justification of the study was that previous studies pointed out substantial inefficiency and potentials to improve rice production, but limited attention have been paid to factors affecting improvements of rice production efficiency. They therefore analyzed mechanization as a key factor to improve technical efficiency. Results revealed that farm mechanization tools significantly improve Myanmar rice production efficiency.

Ndayitwayeko and Korir (2012) estimated technical efficiency of rice production under irrigated system in Gihanga in Burundi and identified the determinants of technical inefficiency. The study used a Cobb-Douglas stochastic frontier production function. On average, they found that there is a room to expend production by efficiently combining inputs. The study revealed further that experience of the rice farmer was enhancing significantly the efficiency level while age of the rice producer was observed to affect negatively the efficiency level. Other factors identified to affect positively the efficiency level were the extension services, farmer's training and timely pesticide delivery.

Le Quang Long *et al.* (2013) examined the TE, AE and EE of the paddy rice producers in CUU LONG DELTA, Vietnam. The study used cost frontier and Cobb-Douglas production function. The results showed that there was an ability of farmers in CUU LONG DELTA to achieve the best potential output if they undertake efficient input combination.

Since these studies are similar to this one, their results have a strong message for this study especially with regard to the problem under study, the methodology, the factors affecting efficiency level and also expected signs of parameters associated with variables. This study being conducted in Burundi, its difference from the study by Ndayitwayeko and Korir (2012) is that, in addition to TE, it will further analyze AE and EE. It will also analyze responsiveness of output with respect to each of the input in the study area. By assessing AE and EE, this study intends therefore to give some insights about how to efficiently allocate resources in rice production in order to do better in deriving profit from rice sub-sector.

2.4 Conceptual Framework

The aim of this study is to analyze the economic efficiency of the smallholder rice producers in Maramvya irrigated scheme, Burundi and determine the factors influencing the level of efficiency among sampled farmers.

Economic efficiency of a firm is the capacity of a firm to produce a predetermined quantity of output at a minimum cost for a given level of technology (Bravo *et al.*, 1997). As detailed by Coelli *et al.* (2005), Economic Efficiency (EE) consists of two components: Technical Efficiency (TE) which measures the ability of the firm to obtain the maximum output from given inputs and Allocative Efficiency (AE), which measures the ability of the firm to use inputs in optimal proportions given their prices. In other words, allocative inefficiency refers to failure to meet the marginal conditions for profit maximization and usually, the test for AE is to compare the marginal value of the physical product (MVP) of an input to its normalized price (Mubarak and Byerlee, 1991). The following figure represents the efficiency measurements in factor-factor space as conceptualized by Farrel (1957).

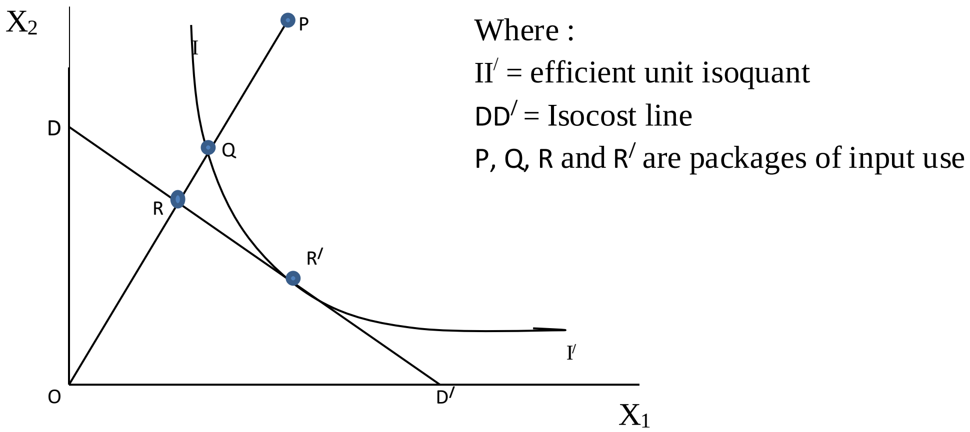


Figure 2: Conceptual framework for efficiency analysis

Figure 2 refers to a situation where a single output is being produced with two inputs, with price ratio represented by the slope of the isocost line, DD$^{/}$. The unit isoquant II$^{/}$ captures the minimum combination of inputs per unit of output needed to produce a unit of output. It describes the technology underlying the production process for a fully efficient farmer (production frontier). From Figure 2, the technical inefficiency level associated to package

P can be expressed by the ratio $\frac{QP}{OP}$, and therefore the TE of the farmer under analysis $\left(1-\frac{QP}{OP}=\frac{OP-QP}{OP}\right)$ would be given by the ratio $\frac{OQ}{OP}$.

Assuming that the farmer has full information on market prices and that the objective of cost minimization is satisfied in such a way that the output price to input price ratio is reflected by the slope of the isocost line DD', the AE that characterizes the farmer at the point P $\left(1-\frac{RQ}{OQ}=\frac{OQ-RQ}{OQ}\right)$ is given by the ratio $\frac{OR}{OQ}$. Farm specific EE is made up with two components which are TE and AE according to Farrell's (1957) definition. Hence the measure of EE comes from the multiplicative interaction of both TE and AE measurements as follows: $EE = \frac{OQ}{OP} X \frac{OR}{OQ} = \frac{OR}{OP}$.

This framework provides a well elaborated econometric approach to measuring TE, AE and EE. The technique consists of specification of a production (or cost) frontier where the output produced (for the case of a production frontier) is explained by input factors (embodied factors), a stochastic component depending on socio economic characteristics of the farmer (disembodied factors) and a random component. For the case of cost frontier, the potential efficient cost is explained by the level of output produced and input prices as well as an error component which include a stochastic component depending on socio economic characteristics of the farmer (disembodied factors) and a random component.

2.4.1 Embodied factors

Embodied change in production level is referred to as change that is captured in factor inputs (Chen, 1997). In this study, factor inputs that are identified to explain the quantity of rice produced in Maramvya irrigated scheme are (i) area planted (land size), (ii) quantity of seeds utilized, (iii) quantity of labour utilized and (iv) quantity of fertilizer used.

2.4.2 Disembodied factors

Disembodied change in production level is the change that is not embodied in factor inputs but takes place not as an input effect to the production process but in the form of better methods that improve the efficiency of factor inputs (Chen, 1997). It is a change that is due to factors affecting efficiency level. For this study, socio economic factors that are assumed to affect efficiency levels are (i) age of the farmer, (ii) sex of the farmer (iii) size of the farmer's household, (iv) off-farm income, (v) education level, (vi) access to extension services, (vii) access to credit, (viii) experience of the farmer in growing rice and (ix) regularity of water for irrigation. These factors are specified in the inefficiency model. From Appendix 1, some factors are hypothesized to have a positive effect while others have negative effect on the level of TE and AE and therefore influence EE level positively or negatively, whether embodied or not.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Overview

This chapter provides the description of the analytical tools employed in the study and the data set. The analytical techniques consist of the SFA model procedures and the Cobb-Douglas production and cost functions specification with maximum likelihood estimation (MLE) of the parameters of the model. Starting with a brief description of the study area, it describes in detail the specification and variables that are considered to analyze the technical, allocative and economic efficiencies of smallholder rice producers in Maramvya irrigated scheme, Burundi. The data set consists of data collection, questionnaire design and sampling design. The detailed description of the methodological process is explained below.

3.2 Description of the Area of Study

3.2.1 Location of the area of study

The study was carried out in Maramvya irrigated scheme located in Bujumbura province (Central West of Burundi), where the Imbo Region Development Society (SRDI), a parastatal company, initiated a scheme by which rice producers are supplied both agricultural inputs (mainly seeds, water and sometimes fertilizers) and other crucial agricultural services on credit basis. SRDI is also the main buyer of rice produced whose payments exclude the deduction of the credit in kind given to farmers.

Maramvya irrigated scheme is one of the irrigated schemes of central Imbo where the bulk of rice is produced in Burundi. It is located 25 km from Bujumbura capital city and it covers a total area of 171 ha. The scheme has a total of 595 farmers and on average, the land holding par farmer is 0.26 ha whereby the production is currently estimated at 4000 kg/ha according to the reports by ISTEEBU (2015). The region is located in the agro-ecological zone of Imbo which has a mean altitude of 1000 m with a mean rainfall of 900 mm and warm tropical climate with temperature ranging between 24°C and 28°C and dry season from five to six months.

3.2.2 Justification for selection of Maramvya irrigated scheme

Maramvya irrigated scheme was selected to be the area of interest for the study for two reasons. First, it is located in the plain of Imbo where the bulk of rice is produced in Burundi. Therefore studying efficiency in rice sector using the highest production scheme as empirical basis shades light and provide insights useful for research, policy and practice. Second, with respect to the study, the scheme offers an advantage of being well organized in such a way that farmers keep record of race farming activities and therefore data on rice production in Maramvya irrigated scheme are realistic and updated to be consistent for the study.

3.3 Research Design

3.3.1 Sampling design

Maramvya irrigated scheme is purposively selected because it is located in the Imbo region where the bulk of rice is produced. Given that the total number of rice farmers in the scheme is known (N = 575), the targeted population is finite and hence the sample size was determined by applying the standard method as proposed by Krejcie and Morgan (1970) as follows:

$$n = \frac{\chi^2 * N * p * q}{d^2 * (N-1) + \chi^2 * p * q} \quad \text{.......... (1)}$$

Where n = sample size, χ^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (at 95% confidence level, $\chi^2 = 3.8416 \approx 3.84$), N = total number of farmers, p = population proportion considered to be 0.5 to provide maximum sample size, q = (1-p) = 0.5 and, d = degree of accuracy expressed as a proportion (d = 0.05). Applying formula (1), the sample size for the study is n = 230 rice farmers.

The list of all farmers in the scheme was obtained from the Maramvya Rice Farmers' Association (ASSOPRO Maramvya). The sample frame was therefore obtained by arranging alphabetically names of all rice producers. Having arranged all 575 rice producers in alphabetical order, simple random sampling was applied to constitute the sample. As such, the sampling interval was $\frac{575}{230} = 2.5 \approx 2$. Hence each 2^{nd} farmer was selected to be interviewed.

3.3.2 Types of data

Secondary and primary data were used for the study. Secondary data such as publications, reports and varied agricultural surveys were sourced from various stakeholders in agriculture sector and particularly in rice sector. These are the Ministry of Agriculture, the Institute of Statistics and Economic Surveys of Burundi (ISTEEBU), the International Rice Research Institute (IRRI), the Institute of Agronomic Sciences of Burundi (ISABU), Imbo Regional Development Society (SRDI) and from past research findings on rice production in Burundi. Using structured questionnaire, primary (cross-sectional) data for season 2016/A have been collected from rice farmers in Maramvya irrigated scheme. The questionnaires captured data on rice yields, input type and usage, production costs and farm-specific and social economic characteristics.

3.3.3 Questionnaire design

A structured questionnaire was used to collect data from farmers regarding to rice yields, input type and usage, production costs and farm-specific and socio-economic characteristics. To acquire more accurate and reliable information to test the hypotheses of the study, the questionnaire was designed in such a way that it would capture data for each variable required for the analytical tool (area planted, labour, seeds, fertilizers and all socio- economic variables assumed to affect efficiency levels among farmers). The questions were closed ended and oriented straightforward to the information needed.

3.3.4 Questionnaire pre-test

The questionnaire was designed based on the knowledge of the researcher on the rice production process in Maramvya irrigated scheme. Therefore, before editing the final copy of the questionnaire, a pre-test was required to test if questions contained in the questionnaire could be well understood by the respondents and if information from the respondents would be accurate with regards to data needed by the researcher. Also before field, a list of pre-requisite information to gather from farmers' association and blocks leaders was addressed. This could help to edit the questionnaire by acquiring the updated information form the scheme.

3.3.5 Questionnaire administration

The interview was conducted by the researcher with the help of enumerators. Before the interview, arrangements were made with the block leaders to schedule appointments with farmers sampled for participation. At the beginning of the interview, the procedure was thoroughly explained to the respondent. After introduction by the researcher, the respondent granted permission to commence then the interview.

3.4 Data Analysis Process

3.4.1 Theoretical model

As already mentioned, the study employed SFA to analyze the technical, allocative and economic efficiencies. The study applied further Cobb-Douglas functional form for the stochastic frontier production and cost function. The Cobb-Douglas functional form for the stochastic frontier estimation has been widely adopted in frontier studies (Hye-Jung Kang and YuYu Tun, 2015). According to Greene (2008), the reasons for choosing Cobb-Douglas functional form include the fact that it has a universally smooth and convex isoquant and the cost function behaving very well (non-declining in output and input prices) and also it allows one-step maximum likelihood estimation by incorporating technical efficiency effects in the model straightforward as developed by Battese and Coelli (1996). Results from technical and allocative efficiencies lead to derivation of economic efficiency levels. The study further developed the inefficiency model to analyze the factors that determine efficiency levels among rice farmers in Maramvya irrigated scheme.

3.4.1.1 Stochastic production frontier

The stochastic production frontier is specified according to Battese and Coelli (1996) as follows:

$Y_i = f(X_i,\beta)\exp(V_i - U_i)$; $i = 1,2, \ldots, n$ ……………………………………………………(2)

Where Y_i = the output produced by the i^{th} farmer; X_i = the vector of inputs used by the i^{th} farmer; β = the vector of parameters to be estimate; V_i = the random error term for the i^{th} farmer assumed to be independently and normally distributed as $N(0, \sigma_v^2)$; U_i represents non-negative random variables which are assumed to account for technical inefficiency in production and are assumed to be independently distributed as truncations at zero with mean μ_i and variance σ_u^2 ($N(\mu_i, \sigma_u^2)$), where: $\mu_i = z_i\delta$, where: z_i is a p×1 vector of variables which may influence the efficiency of a firm and δ is an 1×p vector of parameters to be estimated. The greater the magnitude of U_i from the production frontier, the higher the level of inefficiency of the farmer (Drysdale *et al.*, 1995).

From equation (2), objectives one and two aiming at evaluating the responsiveness of rice produced with respect to each of the inputs used (elasticities) and estimating TE, AE and EE are completed. It is important to note nonetheless that objective two is partly complete as TE only can be derived from the equation mentioned above. As such, the responsiveness of mean output produced by firm i^{th} ($E(Y_i)$) with respect to each input (ε) can be assessed as follows:

$$\varepsilon_a = \frac{\partial lnE(Y_i)}{\partial lnX_a} \quad (3)$$

Moreover, at the individual farmer level, the TE index can be calculated from equation (2) as follows:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(X_i, \beta)\exp(V_i - U_i)}{f(X_i, \beta)\exp V_i} = \exp(-U_i)\,;\ 0 \le TE_i \le 1 \quad (4)$$

Where Y_i is the level of output observed, and Y_i^* the stochastic production frontier (potential output).

3.4.1.2 The stochastic frontier cost function

From the stochastic production frontier, U_i is interpreted as technical inefficiency effects, which cause the firm to operate below the stochastic production frontier. For the stochastic cost frontier function, the error term is altered from (V_i - U_i) to (V_i + U_i) to say that for the cost estimation, farmers who are allocativelly inefficient operate above the cost frontier. The stochastic cost frontier function is specified according to Battese and Coelli (1996) as follows:

$C_i = g(Y_i, p_i, \alpha)\exp(V_i + U_i)$; i = 1,2, … ,n ……………………..……………………(5)

Where C_i = the total production cost observed for the i[th] farmer; Y_i = the output as defined before; p_i = vector of prices of inputs used by the i[th] farmer; α = vector of parameters to be estimated; V_i and U_i are defined as mentioned earlier. According to Coelli *et al.* (2005), the cost function is assumed to be non-declining in output and input prices. The cost efficiency (CE) for each individual farmer is given by the expression:

$$CE_i = \frac{C_i^*}{C_i} = \frac{g(Y_i, p_i, \alpha)\exp(V_i + U_i)}{g(Y_i, p_i, \alpha)\exp(V_i)} = \exp(U_i) \quad \text{……….………………………… (6)}$$

Where C_i is the actual cost and C_i^* is the potential efficient cost for the i[th] farmer. Again, objective two is partly completed by the computation of AE using FRONTIER 4.1 software. This step is fulfilled by introducing a new term, CE which is the inverse of AE (Ogundari and Ojo, 2006). This indirect estimation is based on the specification of frontier cost function by the software as a theoretical minimal bound of cost. It means that all farmers lie above the minimum cost, unless they are on the frontier cost (a 100 percent cost efficiency), implying that CE index is usually above 100 percent. Hence, CE is different from AE (as we know that $0 \leq AE \leq 1$). At each individual farm level, AE index is therefore derived from CE as follows:

$$AE_i = \frac{1}{CE_i} \quad \text{……………………………………………………………………… (7)}$$

3.4.1.3 Computation of economic efficiency

The last step for completing objective two is to compute EE for each individual farmer and this is achieved by combining the above results for TE and AE according to Farrel's (1957) argument that EE is the product of TE and AE. At each individual farm level, EE is therefore computed as follows:

$$EE_i = TE_i * AE_i \quad \text{…………………………………………………………… (8)}$$

3.4.1.4 Inefficiency model

From the stochastic frontier production model, the farmer-specific technical efficiencies are estimated. The estimated efficiencies are then assumed to be explained by socioeconomic and demographic factors. Ui represents non-negative random variables which are assumed to account for technical inefficiency in production and are assumed to be independently distributed as truncations at zero with mean μ_i and variance σ_u^2 (N(μ_i, σ_u^2).

The inefficiency model as proposed by Battese and Coelli (1996) consists in regressing estimated mean inefficiency upon a vector of farm-specific factors affecting inefficiency as follows:

$\mu_i = z_i\delta$ ……………………………………………………………………………… (8)

Where z_i, μ_i and δ are defined as previously.

This specification assumes U_i to be a function of a number of farm-specific factors, which implies that this component is not identically distributed, unless all the coefficients of the factors are simultaneously equal to zero (condition under null hypothesis for hypothesis one).

3.4.2 Empirical model

3.4.2.1 Specification of the stochastic production frontier function

The empirical specification in one-step is based on the model proposed by Battese and Coelli (1996) where inefficiency effects are incorporated in the stochastic trans-log production frontier. This approach enabled the researcher to estimate the determinants and the distribution of the farmer's efficiencies. According to Battese and Coelli (1996), this approach involves regression of output on the input variables as well as social-economic variables that determine inefficiency levels in rice production. The implicit Cobb-Douglas functional form is specified as:

$$\ln(Y_i) = \beta_0 + \sum_{a=1}^{4} \beta_a \ln(X_{ai}) + V_i - U_i;$$

i = 1, 2, 3, … , 230 observations ………………………………………………………….. (9)

Where β_0, $\beta_{a,\ a\ =\ 1,2,3,4}$ are parameters to be estimated, Y_i, X_i, V_i and U_i are defined as previously. Explicitly, the model to be estimated is developed as follows:

$$ln(Y_i) = \beta_0 + \beta_1 lnLand_i + \beta_2 lnLab_i + \beta_3 lnSeed_i + \beta_4 lnFer_i + V_i - U_i\ ;$$

i = 1, 2, 3, …, 230 observations ……………………………………………….…. (10)

Where Y_i = total paddy rice produced by the i^th^ farmer in kg; $\beta_{a,\ a\ =\ 0,1,2,3,4}$ are parameters to be estimated; $Land_i$ = total area planted by i^th^ farmer in ares (a); Lab_i = total amount of labour utilized by the i^th^ farmer in man-days; $Seed_i$ = total quantity of seed utilized by the i^th^ farmer in kg; Fer_i = total quantity of fertilizer utilized by the i^th^ farmer in kg; v_i = random variable for the i^th^ farmer associated with disturbances in the production process; u_i = farm social-economic characteristics related to the production inefficiency.

3.4.2.2 Specification of the stochastic frontier cost function

According to the specification by Battese and Coelli (1996), the implicit Cobb-Douglas stochastic frontier cost function is given by:

$$\ln(C_i) = \alpha_0 + \alpha_y \ln(Y_i) + \sum_{a=1}^{4} \alpha_a \ln(p_{ai}) + V_i + U_i;$$

i = 1,2,3, … 230 observations ……………………………………………………….. (11)

Where C_i = total cost for farm i^th^, α_y and $\alpha_{a,\ a\ =\ 0,1,2,3,4}$ are parameters to be estimated, p_i = input price for the i^th^ farmer and Y_i, V_i, and U_i are as defined previously. Explicitly, the model estimated in this study is specified as follows:

$$ln(C_i) = \alpha_0 + \alpha_1 lnY_i + \alpha_2 lnLandCost_i + \alpha_3 lnLabCost_i + \alpha_4 lnSeedCost_i + \alpha_5 lnFerCost_i + v_i + u_i$$

i = 1, 2, 3, …, 230 observations ……………………... (12)

Where C_i = total cost of producing rice for the i[th] farmer in BIF; $\alpha_{c,\ c\ =\ 0,1,2,\ldots5}$ are parameters to be estimated; Y_i as previously defined; $LandCost_i$ = the land lending price for the i[th] farmer in BIF/are; $LabCost_i$ = the price of labour utilized for the i[th] farmer in BIF/man-day; $SeedCost_i$ = the price of seed for the i[th] farmer in BIF/kg and $FerCost_i$ = the price of fertilizer for the i[th] farmer in BIF/kg

3.4.2.3 Estimation of elasticities, TE, AE and EE

Cobb-Douglas specification offers an advantage that results from estimation are straightforward conclusive about elasticities. Therefore from production function (equation 10), the elasticities of mean output with respect to each of the inputs are derived empirically as follows:

$$\varepsilon_a = \frac{\partial \ln E(Y_i)}{\partial \ln X_a} = \beta_a \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

Where a = 1,2,3,4 are the four inputs used in rice production in Maramvya irrigated scheme.

The standard development of the stochastic frontier model as introduced by Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977) allows estimating TE, AE and EE. Itpostulates that the error term ε_i is made up of two independent components, $\varepsilon_i = V_i - U_i$. Distributional assumptions on ε_i are that V_i is independently and identically distributed normally with mean zero and variance σ_v^2, while U_i is independently and identically distributed half-normally as truncations with mean zero and variance σ_u^2. The parametization of the log-likelihood function for a half-normal model, according to Aigner *et al.* (1977) is that:

$$lnL(Y \backslash \beta, \sigma, \gamma) = -\frac{n}{2} ln\left(\frac{\pi\sigma^2}{2}\right) + \sum_{i=1}^{n} ln\Phi\left(-\frac{\varepsilon_i \gamma}{\sigma}\right) - \frac{1}{2\sigma^2}\sum_{i=1}^{n} \varepsilon_i^2 \quad \ldots\ldots\ldots\ldots \quad (14)$$

Where Y is a vector of log-outputs (rice produced) and $\Phi(x)$ is the cumulative distribution function (cdf) of the standard normal random variable evaluated at x.

Sigma-Squared $\sigma^2 = \sigma_v^2 + \sigma_u^2$ ………………………… …………………………… (15)

and Gamma $\gamma = \frac{\sigma_u^2}{\sigma^2}$ …………………………………………………….... (16)

σ^2 denotes the total variation in the dependent variable (quantity of rice produced) due to an aggregate of technical inefficiency (U_i) and random shocks (V_i). γ explains therefore the impact of inefficiency on the output. The MLE of equations (10) and (12) with FRONTIER 4.1 software provides consistent estimators for β, σ and γ. The parameter γ must lie between 0 and 1. A value of γ close to zero implies that much variation of the observed output from the frontier output is due to random shock. If the value of γ is close to one, it implies that most of the variation in output is explained by inefficiency effects.

Maximizing equation (14) involves in taking the first derivatives with respect to each of the unknown parameters and setting them to zero. However, first order conditions are highly nonlinear and cannot be solved analytically for β, σ and γ (Coelli *et al*., 2005). The solution is found using iterative optimization procedures as by Shaka *et al*. (1985) with FRONTIER 4.1 software program, in the consideration of specification of equations (10) and (12) where the functional form of the frontier is Cobb-Douglas and the number of parameters is known. Then the estimated technical efficiency for farm i^{th} can be depicted in the conditional expectation as follows:

$\widehat{TE} = E\{\exp(-u_i)\} = 2\Phi(-\sigma_u)exp\left\{\frac{\sigma_u^{\,2}}{2}\right\}$ ……………………………………….………. (17)

3.4.2.4 Determination of socio-economic factors affecting efficiency levels

Objective three is completed by specification of inefficiency model which involves regressing the inefficiency component (U_i) to the farm social-economic characteristics. Equation (8) is empirically specified as follows:

$$U_i = \delta_0 + \delta_1 Age_i + \delta_2 Sex_i + \delta_3 HHSiz_i + \delta_4 OffFarm_i + \delta_5 Adult_i + \delta_6 Prim_i + \delta_7 Second_i + \delta_8 CredAcc_i + \delta_9 Exp_i + \delta_{10} Irr_i$$

;

i = 1, 2, 3, …, 230 observations ……………………………………………………(18)

Where u_i = as defined before; $\delta_{b,\ b = 0,1,2,\ldots 10}$ are parameters to be estimated; Age_i = age of the i[th] farmer in years; Sex_i = sex of the i[th] farmer (1 = male, 2 = female); $HHSiz_i$ = size of the family of the i[th] famer (number of persons); $OffFarm_i$ = off-farm income (1 = if farmer earned off-farm income, 0 = if farmer did not earn off-farm income); $Adult_i$ = attainment of adult education level of the i[th] farmer (1= attained adult education, 0 = otherwise); $Prim_i$ = attainment of primary education level of the i[th] farmer (1= attained primary education level, 0 = otherwise); $Second_i$ = attainment of secondary education level of the i[th] farmer (1= attained secondary education, 0 = otherwise); $CredAcc_i$ = Access to credit by the i[th] farmer (1 = if farmer accessed to credit, 0 = no access to credit); Exp_i = experience of the farmer i[th] in years; Irr_i = shortage in water for irrigation for the i[th] farmer (1= if the farmer has faced shortage, 0 = no shortage).

From equation (18), parameters for the inefficiency model were derived. The task under this sub-section is to test the significance and analyze the sign of parameter associated with each socio-economic characteristic, and conclusion from the test would allow to reject or fail to reject hypothesis three.

It is important to note that equations (10), (14) and (18) for the case of frontier production or (12), (14) and (18) for the case of frontier cost are usually estimated simultaneously using MLE procedures with FRONTIER 4.1 software program.

CHAPTER FOUR

4.0 RESEARCH FINDINGS

4.1 Overview

This study aims at estimating the extent to which farmers in the Maramvya irrigated scheme can raise their productivity and profitability if they efficiently adjust inputs use. Hence, output responsiveness with respect to the level of inputs use is examined and TE, AE and EE are estimated. Facts affecting efficiency levels among rice farmers are determined also.

This chapter presents findings from estimation with respect to each of the three specific objectives of this study. It presents the empirical findings from the analytical process described in chapter Three. A descriptive analysis of socio-economic characteristics and variable data of the sampled farmers precede the discussion of study findings. The findings are presented in a tabular form and interpreted individually with respect to each of the specific objectives.

4.2 Socio-economic Characteristics of Respondents

Socio-economic Characteristics that are discussed are those susceptible of influencing the efficiency levels among rice farmers in the scheme and are specified in the inefficiency model. These characteristics include age, sex, household size, off-farm income, educational level, access to credit, years of farming experience and availability of water for irrigation as indicated in Table 1.

Table 1: Socio-economics characteristics of rice producers in Maramvya irrigated scheme, Burundi

Characteristics	Frequency	Percentage
Age (Years)		
<15	0	0
15-24	1	0.43
25-34	16	6.95
35-44	44	19.13
45-54	64	27.82
55-65	69	30.00
>65	36	15.65
Total	**230**	**100.00**
Sex		
Male	150	65.22
Female	80	34.78
Total	**230**	**100.00**
Household Size		
1-4	23	10.00
5-8	108	46.96
9-12	82	35.65
>13	17	7.39
Total	**230**	**100.00**
Off-farm Income		
Off-farm Income	62	26.9565
On-farm Income Only	168	73.0435
Total	**230**	**100.00**
Education Level		
No formal Education Level	88	38.2609
Adult Education Level	19	8.2609
Primary Education Level	107	46.5217
Secondary Education Level	16	6.9565
University Education Level	0	0.0000
Total	**230**	**100.00**
Access to credit		
With Access to Credit	167	72.61
With no Access to Credit	63	27.39
Total	**230**	**100.00**
Experience (Years)		
<5	1	0.43
5-10	16	6.96
11-15	20	8.70
16-20	52	22.61
21-25	10	4.35
>25	131	56.96
Total	**230**	**100.00**
Water availability		
Have Faced Shortage of Water	46	46
No Shortage of Water	184	184
Total	**230**	**100.00**

4.2.1 Age and sex

Age as one of socio-economic characteristics of rice producers in Maramvya irrigated scheme ranges from 22 to 85 years. From Table 1, we can see that majority of the household heads (30%) in the study area are aged between 55 and 65 years followed by 27.8% of the 45 to 54 years category. This implies that most of household heads in the study area are too old compared to the mean age of 51 years. With these findings, it is apparent that most of the rice farmers are above the active age and they probably do not have enough capacity to manage their farms.

Socio-economic characteristic of rice farmers in the study area indicated that 65.22% of the respondents are male while 34.78% were female. This means that male population was more involved in rice production than female.

4.2.2 Household size

The findings show that the average household size in the study area is 8 persons with the majority of families (46.96%) having the size ranging between 5 and 8 persons. It is also revealed that the proportion of families with large size (compared to the mean of 8 persons) is important, that is 35.65% for the class of 9 to 12 persons and 7.39 above 13 persons. This implies that rice farmers in the study area have to produce much in order to be able to feed their families and also derive surplus to fulfill other needs.

4.2.3 Off-farm income

The study findings reveal that 73.04% of rice farmers in the study area have no other sources of income other than farming activities. It implies that only a proportion of 26.95% have access to other sources of income. This means that majority of rice farmers in Maramvya irrigated scheme have to yield much from farming activities in order to fill the capital gap, unless they have access to credit in financing institutions.

4.2.4 Education level

Apparently, majority (46.52%) of the sampled farmers have primary education level. It was found also that a considerable percentage (38.26%) has not gone to formal school. Furthermore, the findings revealed that there is no single farmer with tertiary education in the study area. This has led to non-inclusion of the tertiary category for the variable "education level" during estimation of the analytical model after realizing this state of nature during data collection.

4.2.5 Access to credit

Within the study area, it has been revealed that 72.61% of rice farmers have access to credit facilities. According to information obtained from respondents, this is due to the fact that farmers in Maramvya irrigated scheme are affiliated with farmer's association which offers an advantage of reliability and confidence with regard to financing institutions. On the other side, a proportion of 27.39% rice farmers have no access to credit and have problem to fill the capital gap during intense activities.

4.2.6 Experience

The mean farming experience of the rice farmers in the study area was 25 years with the majority ranging above that mean (56.96%). This implies that most of the rice farmers have been in rice production for a long time and this matches with what we have found for age of rice farmers where the majority of farmers have aged above 51 years. Following this observation, we can conclude that most of plots used to grow rice in the study area are under family ownership where property rights are transmitted from generation to generation.

4.2.7 Shortage of water for irrigation

The study findings have shown that rice farmers in the study area have no shortage of water in general (20% with shortage against 80% without shortage of water). That would lead to a conclusion that the small proportion of rice farmers facing shortage of water may perform poorly in terms of rice produced. According to information obtained from respondents, individual shortage of water is due to the miss leveling of farmers' plots and therefore the water captured from the canal fail to reach to whole surface of the plot. This leads to draught of some parts of rice plants before reaching maturity.

4.3 Production and Input Variables Description

Description of input use quantities and prices aims at pointing out the characteristics nature of subsistence farming activities that dominate the rice production system and hence contributes to the understanding of efficiency levels and sources of inefficiency for rice producers in Maramvya irrigated scheme.

Table 2: Descriptive statistics of production levels and input variables for rice in Maramvya irrigation scheme

Variables	Minimum	Maximum	Mean	Std. Deviation
Quantity of Rice Produced (kg/ha)	546.34	6912.00	3547.00	1027.45
Land Cultivated (ha)	0.09	0.92	0.26	0.12
Quantity of Labour Utilized (man-days)	194.74	543.59	422.42	52.06
Quantity of Seed Utilized (kg/ha)	43.48	240.00	119.58	37.54
Quantity of Fertilizer Utilized (kg/ha)	100.00	800.00	377.71	124.71
Price of the Land (BIF/are)	8160.00	177000.00	41128.00	30567.52
Price of Labour (BIF/man-day/day)	2718.00	5832.00	4108.60	614.15
Price of Seed (BIF/kg)	690.00	10332.00	1011.40	622.41
Price of Fertilizer (BIF/kg)	960.00	2286.00	1307.50	128.33

4.3.1 Quantity of the produced rice

The summary statistics of the rice production and variables used for the stochastic production and cost function analyses is presented in Table 2. The findings indicates that the average rice production per farmer and per single season in the study area was 3547 kg/ha. This finding is within the estimation by ISTEEBU (2015) where it is reported that average rice production per hectare is 4 tonnes/ha for irrigated rice production.

4.3.2 Land cultivated and price of the land

On the other side, the analysis of inputs used revealed an average farm size of 0.26 ha per farmer and this confirms that the study covered smallholder rice farmers where farms are basically family managed. It has been revealed also that the majority (63.04%) of the rice farmers cultivated on small farm size ranging between 0 and 0.25 ha. From what we have found on age and experience of rice farmers, it can be concluded that most of land cultivated is not rented from private persons. The price of land used reflected therefore the payments (for acquiring rights to exploiting the scheme) to the owner of the scheme, the SRDI society. Hence the average price of the land was found to be 41128 BIF/0.25ha and the average total land cost represents 1.82% of the total cost of rice production in the study area.

4.3.3 Quantity of utilized labour and price of labour

The average labour used was 422.42 man-days per season from first tillage to packaging. Referring to the small size of land holding in the study area (0.26 ha/farmer), we can conclude that operations are too manual and require much labour. Furthermore, the share of total labour cost in the total cost of rice production per season represents 72.64% on average in the study area. This huge amount of labour cost in the total cost of rice production would reflect the fact that techniques for rice production are rudimental and rice farmers depend heavily on human labour to do farming operations.

4.3.4 Quantity of Seed Utilized and Price of Seed

Findings revealed that on average, the quantity of seed utilized is 119.58 kg/ha. This level of seed utilization is almost the double of what is recommended from SRDI (60 kg/ha). According to the information received from sampled farmers, the behavior is motivated by the fact that some plots are not well leveled and thus water for irrigation may not cover the whole plot surface. Also, some other plots are under normal ground level and rice crops may face floods during growing period. Other arguments from farmers are the fear of diseases and other impediments before rice reaching maturing. Hence rice farmers may pretend reducing yield risk in doing so.

Due to this mismanagement of seed input, it could be expected that farmers utilizing less seed input with regard to SRDI and other research stations recommendations, and who further do a close management of their farms, may be more efficient and hence we may observe an inverse relationship between quantity of seed and yield level. The price of seed was on average 1011.40 BIF/kg and the total seed cost was not important on average as it was on average 5.06% of total cost of rice production in the study area.

4.3.5 Quantity of fertilizer utilized and price of fertilizer

The level of fertilizer utilization was found to be 377.71 kg/ha an average in the study area. On contrast with seed use, it has been found that fertilizer input is underutilized in the study area. This is due to the lack of capital as the majority of rice farmers have no off-farm income (73.04% of total rice farmers) and reliable sources of credit that would enable them to reduce capital gap and buy enough quantity of fertilizers. From that observation, it could be expected that farmers using enough quantity of fertilizers yield more than those ones using small amount of fertilizers, and hence fertilizer input could be assumed to have a significant positive impact on the level of rice produced. The price of fertilizer was 1307 BIF/kg and it has been revealed that total fertilizer cost ranked second important cost (20.48% of total cost of rice production) after labour variable.

4.4 Results from Estimations

4.4.1 Post estimation tests

The maximum-likelihood estimates (MLE) of the parameters of the production and cost functions, given in equations (10), (12), and (14) were estimated using the computer program FRONTIER 4.1 by Coelli (1996). The results for parameter estimates are presented in Tables 3. Before we can infer from these results, post estimation tests for the fitness of models and existence of inefficiency effects in the variation of rice produced and total cost of production have been done for both production and cost frontiers.

Table 3: Results from estimation

Frontier Production Function				**Frontier Cost Function**			
Variables	**Parameters**	**Coefficients**	**t-ratio**	**Variables**	**Parameters**	**Coefficients**	**t-ratio**
Intercept	β_0	3.26***	13.38	Intercept	α_0	-0.14	-0.13
LnLand	β_1	0.41***	2.69	LnY	α_1	0.18***	5.08
LnLab	β_2	0.45***	3.07	LnLandCost	α_2	0.56***	39.27
LnSeed	β_3	-0.11*	-1.83	LnLabCost	α_3	0.52***	6.70
LnFer	β_4	0.24***	4.34	LnSeedCost	α_4	0.11*	1.92
				LnFerCost	α_5	0.09	0.78
Fitness of the Model				**Fitness of the Model**			
Log-likelihood Function		-18.96		Log-likelihood Function		105.48	
Likelihood Ratio Test Statistic	LR	74.32***		Likelihood Ratio Test Statistic	LR	27.65***	
Variance Parameter for the Error Component				**Variance Parameter for the Error Component**			
Sigma-Squared	$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.46**	2.14	Sigma-Squared	$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.02***	10.15
Gamma	$\gamma = \frac{\sigma_u^2}{\sigma^2}$	0.92***	23.78	Gamma	$\gamma = \frac{\sigma_u^2}{\sigma^2}$	0.46	0.56

*, ** and *** Significant at 10%, 5% and 1% respectively

From Table 3, the LR test statistic (74.32) is significant at 5% level of significance, indicating that the sampled farmers have acceptable likelihood of being a true representative of the targeted population, which is smallholder rice producers in Maramvya irrigated scheme, Burundi. With respect to each variable included in the model, the coefficients associated with land, labour and fertilizer variables were all significant at 5 % level of significance whereas coefficient associated with seed variable was not. This means that independent variables included in the model globally explain the production level in the study area.

From estimation of the cost function, the explanatory power of variables included in the model was proved as the LR test statistic (LR = 27.65) was significant at 5% level of significance. Also with the fitness of cost modeling, it has been revealed that variables included in the cost model are globally explaining variation in total cost of producing rice in the study area. The coefficient associated with production level, price of land and price of labour were 0.18, 056 and 0.52 respectively and were all significant at 5% level of significance. However, coefficients associated with price of seed and price of fertilizer were insignificant at 5% level of significance. All coefficients associated will cost variables were positive, implying that the assumption of non-decrease of cost function in output and input prices was satisfied.

4.4.2 Derivation of elasticities

In the view of objective one of this study, results of the first order Cobb-Douglas production function coefficients from Table 3 are straightforward conclusive as they are interpreted as the measure of responsiveness of the output with respect to each of the inputs. Based on this argument, output elasticities of each of the physical input used and their mean values are reported as they appear in Table 3:

Table 4: Input elasticities of the frontier production function

Input	Elasticity
Land	0.41
Labour	0.45
Seed	-0.11
Fertilizer	0.24
Return to Scale	**0.99**

From Table 4, elasticities of production with respect to land, labour and fertilizer were 0.41, 0.45 and 0.24 respectively were positive and significant at 1% level of significance. This means that levels of utilization of these inputs were below the optimal levels and hence an increase in input use for the three inputs would yield positive quantities of rice produced. The elasticity of production with respect to land (0.41) was statistically significant at 1% significance level. This means that, at that level of significance, a 1% increase in areas of land used in the production of rice would lead to an increase of 0.41% kg in the mean rice produced, holding labour, seed and fertilizer inputs constant. The elasticity of production with respect to labour (0.45) was statistically significant at 1% level of significance. The implication is that a 1% increase in man-days of labour used would increase the mean rice produced by 0.45% kg, holding land, seed and fertilizer inputs constant. The elasticity of production with respect to fertilizer input (0.24) was statistically significant at 1% level of significance. It implies that at 1% increase in kg of fertilizer applied would lead to 0.24% kg increase in mean rice produced, holding land labour and seed inputs constant.

The elasticity of production with respect to seed input (-0.11) was negative and statistically significant at 10% level of significance, implying that, at that level of significance, a 1% increase in kg of seed used will lead to a decrease of 0.11% kg in mean rice produced, holding land, labour and fertilizer inputs constant. The justification being the reasons already detailed in section 4.3.4, where rice producers were on average over-utilizing seed input if we refer to what was recommended by research stations. The negative relationship between seed input and quantity of rice produced gave message that the better way of efficient use of seed input would be to reduce quantities that were applied at the period of study.

The above results demonstrated highest responsiveness of rice produced with respect to labour followed by land and fertilizer came at the last position while seed increase impact negatively the quantity of rice produced. Labour and land are the major inputs which improve productivity followed by fertilizer. These results led to rejection of the first null hypothesis stating that there is no statistically significant difference in responsiveness of output with respect to each of inputs used for rice production in Maramvya irrigated scheme.

Concluding the assessment of rice productivity in the study area, results in Table 4 showed that rice production technology in the study area exhibits a decreasing positive return-to-scale (RTS = 0.99). This means that rice producers are producing in stage two of production process and hence were likely to be more or less technically efficient in allocating their resources even though they were not a 100% efficient.

4.4.3 TE, AE and EE estimation

With regard to objective two, the aim was to estimate TE, AE and EE and state whether rice producers in the study area still have a room to expend their productivity and profitability. Before deriving these indices, an assessment of existence of inefficiency effect in the variation of rice produced and total cost in rice production was required.

From Table 3, the estimated value of gamma ($\gamma = 0.92$, the variance parameter) for frontier production function was significant at 5% level of significance which indicated that technical inefficiency effect had an influence on the variation of rice produced in the study area at that level of significance. In other words, the variation in rice produced in Maramvya irrigated scheme was 92% explained by failure of farmers to efficiently use inputs technically.

On the side of frontier cost function, the cost inefficiency effect has insignificant influence on the variation of the total cost of producing rice, if we consider a significance level of 5%. But since allocative inefficiency is indirectly derived from cost inefficiency by inverting the cost inefficiency index (Ogundari and Ojo, 2006), we may not directly capture the significance of influence of allocative inefficiency effect, unless we combine technical and allocative inefficiencies.

Since there was technical inefficiency effect and given that economic efficiency combines technical and allocative efficiencies as defined earlier, the second null hypothesis stating that farmers are not economically inefficiency was rejected at 5% level of significance and therefore we were able to support the claim that rice producers in Maramvya irrigated scheme were economically inefficient. Following to the above conclusion, TE, AE and EE indices for each individual farm level were computed as follows:

Table 5: Summary of distribution of TE, AE and EE indices for rice production in Maramvya irrigated scheme

Classes	TE		AE		EE	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
0.00 - 0.14	1	0.43	0	0.00	1	0.43
0.15 - 0.29	0	0.00	0	0.00	1	0.43
0.30 - 0.44	2	0.87	0	0.00	21	9.13
0.45 - 0.59	16	6.96	5	2.17	45	19.57
0.60 - 0.74	13	5.65	154	66.96	134	58.26
0.75 - 0.89	72	31.30	71	30.87	28	12.17
0.90 - 1.00	126	54.78	0	0.00	0	0.00
Total	230	100.00	230	100.00	230	100.00
Mean	0.82		0.71		0.58	
Std. Deviation	0.13		0.06		0.11	
Range	0.82		0.32		0.71	
Minimum	0.14		0.57		0.08	
Maximum	0.97		0.89		0.79	

From Table 5, mean TE was found to be 82% implying that on average, rice producers in Maramvya irrigated scheme could raise their production level about 18% if they adjust input efficiently. This finding is in consonance with findings by Ndayitwayeko and Korir (2012) who confirmed that there is a room to expand rice production. Mean AE was found to be 71% implying that rice farmers are not producing with minimal cost and indeed farmers still have to reduce their cost about 29% in order to be efficient allocatively.

Globally, the mean EE was 58%. This means that rice producers in the study area could raise their profitability about 42% if they could undertake efficient allocation of inputs with the existing technology at the time of the study. On average TE level was higher than AE and EE but showed a strong variation within sampled farmers, with a minimum level of 0.14 and a maximum of 0.97. This high level of TE compared to AE and EE was confirmed by decreasing RTS of 0.99 proving that rice farmers were likely to be technicaly efficient compared to allocative and economic efficiency. These results are consistent with those reported by Battese and Coelli (1996), Ogundari and Ojo (2006), Le

Quang Long *et al.* (2013) and Magreta *et al.* (2013) where findings revealed that rice farmers are more likely technically efficient than they are allocatively or economically.

4.4.4 Assessment of factors affecting efficiency levels

As aimed by objective three of this study, this section intends to identify some of the factors that influence efficiency levels among rice farmers in Maramvya irrigated scheme. The results for this analysis are important to be used as basic information to agricultural policy makers on what factors should interventions be focused to improve rice productivity. Table 6 summarizes results on determinants of economic efficiency levels among sampled farmers.

Table 6: Results for estimation of inefficiency model

Variables	Parameters	Coefficients	t-ratio
Intercept	δ_0	0.6869^{***}	17.31
Age	δ_1	-0.0017^{**}	-2.04
Sex	δ_2	0.0046	0.31
HHsize	δ_3	-0.0025	-1.33
Off - farm	δ_4	0.0029	0.21
Adult	δ_5	0.1105^{***}	5.91
Prim	δ_6	0.0573^{***}	3.55
Second	δ_7	0.0602^{***}	3.04
CredAcc	δ_8	-0.0535^{***}	-3.80
Exp	δ_9	0.0010	1.20
Irrig	δ_{10}	-0.1285^{***}	-6.93
		F Statistic	**10.10^{**}**
		R-Squared	**0.36**

*, ** and *** Significant at 10%, 5% and 1% respectively

Results from estimation of the inefficiency model showed that the model is globally significant at 5% level of significance since F test statistic (F = 10.10) is greater than critical value at that level of significance. However low R – Squared (R^2 = 0.36) indicated that socio-economic variables included in the model are far from being able to explain the total variation of efficiency levels among rice farmers in the study area and hence further studies are needed to determine other potential factors influencing efficiency levels in the study area.

The coefficients associated with levels of education of the farmer were positively significant at 5%. This means that attainment of education level, whether adult, primary or secondary, would improve positively the efficiency level of rice producers in Maramvya irrigated scheme. That finding was consistent with what was expected as long farmers who are educated are more likely to have ability to adapt new techniques, but also rice production operations are so many and need minimum recording of information concerning production process form first tillage to storage of rice produced. Therefore rice farmers with no minimum education are likely to be inefficient in managing their farms.

Age, access to credit and the shortage of water for irrigation with coefficients -0.0017, -0.0534, -0.1285 respectively were found to negatively influence efficiency levels among rice producers at 5% level of significance. Given age distribution of rice farmers which revealed that farmers were above their active age, this was consistent with what was expected as long as farmers may not have enough force to manage their farms and for this reason, younger farmers are likely to be more efficient than old ones. Access to credit also was expected to negatively influence efficiency levels because farmers with access to credit are likely to miss behave in allocating their budget to input resources, compared to those ones with no access to credit, indeed whom are more budget constrained because of lack of enough capital. Shortage of water for irrigation obviously harms efficiency since water is premier condition for rice growing.

Other factors like sex of the farmer, off-farm income earning and experience of the farmer were found to positively influence efficiency levels in the study area, but their influence was not significant at 5% level of significance. For sex variable, this was interpreted as an advantage of being male in producing rice because it would enhance efficiency level. That interpretation holds also for experience of farmers, where more experienced farmers are in a better position of understanding and integrating agricultural instructions and apply more rapidly new techniques. The influence of household size was insignificant at 5% level of significance, but with a negative impact on the level of efficiency. This was in sentence with our expectation because a big number of family members would lead to a big amount of charges, especially in the study area where we have found that most of farmers relied on on-farm income and where family labour was less employed on family farms.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

This chapter summarizes, concludes and gives recommendations based on findings of the study. It starts by recalling what were the objectives of the study, highlights keys points of the theory underlying the study and the methodology used to obtain findings. It gives conclusion from findings and draws some recommendations with regard to research findings.

Rice is becoming important crop if we consider its potentials to fight food insecurity and reduce poverty for Burundi, a country for which agriculture contributes 30% to GDP, employs more than 90% of active population and earns Burundi more than 50% of foreign currency.

Given its importance with regard to both poverty and food security perspective, rice is at the center of key strategic roadmap documents for agricultural development, namely the Strategic Framework for Economic Growth and Poverty Reduction (SFEGPR), National Agricultural Strategy 2008 – 2015 (NAS), National Program for Food Security 2009 – 2015 (NPFS), National Program for Agricultural Investment 2012-2017 (NPAI) and finally National Strategy for Development of Rice Sector 2014 (NSDRS-B). The latter being focused specifically on rice sector, four specific objectives were pursued; amelioration of rice productivity, rice importation reduction, amelioration of rice farmers' revenue and exportation of rice surplus (GoB, 2014).

In that context the Government of Burundi and non-government stakeholders are actively investing in rice production increase. Surveying literature, it has been revealed that interventions made to increase rice profitability have been basically agronomic while improvement of managerial performance of rice producers as a source of increased productivity and profitability have been less surveyed. Systematic literature review done in this study shows little evidence on the existence of research on Economic Efficiency (EE) for Burundi rice sub-sector, that is an analysis that combines both TE and AE.

The study aimed at assessing rice productivity and EE in Maramvya irrigated scheme as one of the scheme where the bulk of rice is produced in Burundi but also it aimed at identify factors that determine efficiency levels among smallholder rice producers in the scheme, with a view of informing government and rice production stakeholders' decision processes.

The theory guiding the study was the efficiency theory which has a long and rich literature. It based the analytical framework on the Farrel's (1957) conception that has brought the possibility of estimating theoretical ideal frontier functions previously defined by Koopmans (1951) and Debreu (1951), and which undergone refinements overtime. The development by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) is the standard form that was applied in this study as supported Greene (2008).

The study was carried out in Maramvya irrigated scheme located in Bujumbura province (Central West of Burundi). The area is one of the irrigated schemes where the bulk of rice is produced in Burundi. It is located at 25 km to Bujumbura capital city and it covers a total area of 171 ha. The scheme totalizes 595 farmers and on average, the land holding par farmer is 0.26 ha whereby the production is currently estimated at 4 000 kg/ha according to the reports by ISTEEBU (2015). The area of study was purposively selected and by applying the standard method as proposed by Krejcie and Morgan (1970) a random sample of 230 rice farmers has been selected to be interviewed. Cross-sectional data for season 2016/A have been collected using a structured questionnaire and the questionnaires captured data on rice yields, input type and usage, production costs and farm-specific and social economic characteristics.

The study used SFA to analyze TE, AE and EE. The study applied further Cobb-Douglas functional form for the stochastic frontier production and cost function. The Cobb-Douglas functional form was selected because it has been widely applied and it offers advantage of satisfying assumptions on production and cost function. It also allows one-step maximum likelihood estimation by incorporating technical efficiency effects in the model straightforward as developed by Battese and Coelli (1996).

Findings revealed that land, labour and fertilizer inputs had elasticities of 0.41, 0.45 and 0.24 and positively influence levels of rice produced at 5% level of significance while seed input elasticity (-0.11) was negatively influencing rice production level, but with insignificant effect at 5% level of significance. TE, AE and EE index were found to be 0.82, 0.71 and 0.58 respectively on average. Factors affecting positively efficiency levels within sampled farmers were found to be sex, off-farm income, education level and experience with education level only significantly affecting efficiency levels at 5% level of significance. Factors like age, household size, access to credit and shortage of water for irrigation were impacting efficiency level negatively with household size having insignificant effect at 5% level of significance.

5.2 Conclusions

This study aimed estimating the extent to which farmers in the Maramvya irrigated scheme can raise their productivity and profitability if they efficiently adjust inputs use. In that purpose, output responsiveness with respect to the level of inputs use is examined and TE, AE and EE are estimated. Facts affecting efficiency levels among rice farmers are determined as well.

Firstly from objective one, the aim was to estimate elasticities of mean output with respect to each of the inputs used and first null hypothesis derived from that objective stated that there is no statistically significant difference in responsiveness of rice produced with respect to each of inputs used. Land, labour, seed and fertilizer elasticities were 0.41, 0.45, -0.11 and 0.24 respectively and put aside seed elasticity which was negative and insignificant at 5% level of significance, the three other input were found to positively explain rice production level at 5% level of significance. This means that levels of utilization of these inputs (land, labour and fertilizer) were below the optimal levels and hence an increase in input use for the three inputs would lead to increase in rice production. The above results demonstrated highest response of rice produced with respect to labour followed by land and fertilizer came at the last position while seed increase impact negatively the quantity of rice produced. These results led to rejection of the first null hypothesis stating that there is no statistically significant difference in responsiveness of output with respect to each of inputs used for rice production in Maramvya irrigated scheme. Furthermore, results demonstrated that rice production process in the study area exhibits a decreasing positive return-to-scale (RTS = 0.99) and this means that rice producers were likely to be more technically efficient in allocating their resources even though they were not a 100% efficient, for instance seed input was over-utilized. Land and labour inputs being more responsive of rice production in the study area and referring to the small size of land holding in the study area (0.26 ha/farmer) where farmers used huge amount of labour with a share of total labour cost in the total cost of rice production representing 72.64%, this would reflect the fact that techniques for rice production are rudimental and rice farmers depend heavily on human labour to do farming operations.

Secondly from objective two, the aim was to estimate the TE, AE and EE indices and the second null hypothesis was that rice farmers in Maramvya irrigated scheme were not economically inefficient. Findings revealed that there was an inefficiency effect in the variation of rice produced at 5% level of significance therefore the second null hypothesis was rejected at that level of significance. On average, TE, AE and EE indices were 0.82, 0.71 and 0.58 respectively and it implies that rice producers were more likely to be technically efficient than there allocatively or economically. Hence rice producers in Maramvya irrigated scheme could raise their profitability by 42% by efficiently adjusting inputs with the existing technology at time of the study.

Thirdly and finally, objective three aimed at assessing socio-economic characteristics affecting efficiency levels in Maramvya irrigated scheme and it was hypothesized that farm specific characteristics and socio-economic factors do not affect efficiency levels for rice production in Maramvya irrigated scheme. Findings revealed that attainment of any education level, whether adult, primary or secondary, would improve positively the efficiency levels of rice producers in Maramvya irrigated scheme at significance level of 5%. This implies that farmers who are educated are more likely to have ability to adapt new techniques, but also rice production operations are so many and need minimum recording of information concerning production process. Age, access to credit and the shortage of water for irrigation were found to negatively influence efficiency levels among rice producers at 5% level of significance. Age distribution of rice farmers revealed that farmers were above their active age and this was consistent with what was expected as long as farmers may not have enough force to manage their farms and for this reason, younger farmers are likely to be more efficient than old ones. Access to credit also was expected to negatively influence efficiency levels because farmers with access to credit are likely to miss behave in allocating their budget to input resources, compared to those ones with no access to credit whom are more budget constrained because of lack of enough capital. Shortage of water for irrigation obviously harms efficiency since water is premier condition for rice growing.

Other factors like sex of the farmer, off-farm income earning and experience of the farmer were found to positively influence efficiency levels in the study area, but their influence was not significant at 5% level of significance. For sex variable, this was interpreted as an advantage of being male in producing rice because it would enhance efficiency level. That interpretation holds also for experience of farmers, where more experienced farmers are in a better position of understanding and integrating agricultural instructions and apply more rapidly new techniques. The influence of household size was insignificant at 5% level of significance, but with a negative impact on the level of efficiency. This was in sentence with our expectation because a big number of family members would lead to a big amount of charges, especially in the study area where we have found that most of farmers relied on on-farm income and where family labour was less employed on family farms.

5.3 Recommendations

With regard to findings of this study following recommendations have been formulated to rice producers, Government and SRDI which is the owner of the scheme but also some further studies are recommended to complete the current study.

Firstly, being revealed that increase in rice production was highly depending on land use and labour utilization, the implication is that rice production technology was rudimental and the exploitation was family based. It could be recommended to rice producers to apply new technologies for instance intensification of fertilizer use. Farmers should implement recommendation from extension services, for instance adjust seed use to what is recommended by experimental stations.

Secondly, the study revealed that there is a 42% room to expend rice productivity and profitability in Maramvya irrigated scheme. But some factors impacting efficiency levels may be exogenous to rice farmers' entertainment as socio-economic characteristics explained only 36% of variation of efficiency levels. Government and stakeholders involved in rice production increase should focus their intervention on permanent extension services aiming at acquiring of new skill in rice production techniques. In the long run, the Government should focus on education as it improves significantly efficiency in rice production. Furthermore, miss use of seed was due mostly to the fear of shortage of water because some plots were not well leveled. Intervention should be made by SRDI to maintain canals for irrigation because the cost of maintenance would be probably beyond farmers' capacity. Input market and input availability is also a task to be performed by Government and policy makers in order to reduce the gap in cost inefficiency.

Lastly, the study recommends further studies on the following:

(i) The technical, allocative and economic gaps were found to be 18%, 29% and and 42% respectively. It can be assumed that other types of gaps may exist for instance scale inefficiency (technology restriction that is constant or non-constant return to scale – findings revealed a relatively constant return to scale), structural inefficiency referring to how an industry keeps up with its performance of best practice (van Dijk *et al.*,

2016) and inefficiency due to motivation, information, monitoring, and agency problems within the firm, the so called "X-inefficiency" by Leibenstein (1966). Further studies are needed to disentangle all these types of gaps in rice production.

(ii) $R^2 = 0.36$ for the inefficiency model is small implying that other studies should focus on other factors that are not included in the model that may influence efficiency levels among rice producers in Maramvya irrigated scheme.

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APPENDICES

Appendix 1: Expected signs of variables included in the model

Variable	**Types of variable**	**Description**	**Unit**	**Expected sign**
Input variables				
Area planted	Continuous	Total area used to grow rice for the period of study	hectare	+
Labour	Continuous	Amount of labour utilized	man-days	+
Seed	Continuous	Total quantity of seed used	kg	+
Fertilizer	Continuous	Total quantity of fertilizer utilized	kg	+
Inefficiency model variables				
Age	Continuous	Age of the rice farmer	Years	-
Sex	Binary	0 = Female 1 = Male	Dummy	+
Household size	Continuous	Number of persons in the farmer’s household	Number of family members	-
Off-farm income	Binary	0 = no off-farm income 1 = off-farm income	Dummy	+
Education level	Categorical	0 = No formal education 1 = otherwise	Dummy	+
Access to credit	Binary	0 = no access to credit 1 = have access to credit	Dummy	-
Experience	Continuous	Years in rice farming	Years	+
Regularity of water for irrigation	Binary	0 = no shortage 1 = shortage	Dummy	-

Appendix 2: TE, AE and EE indices for smallholder rice producers in Maramvya irrigated Scheme

Firm#	TE	AE	EE	Firm#	TE	AE	EE	Firm#	TE	AE	EE	Firm#	TE	AE	EE	Firm#	TE	AE	EE
1	0.78	0.66	0.52	50	0.87	0.67	0.58	99	0.87	0.67	0.58	148	0.92	0.76	0.70	197	0.85	0.71	0.61
2	0.83	0.64	0.53	51	0.86	0.69	0.59	100	0.46	0.62	0.29	149	0.78	0.71	0.56	198	0.85	0.77	0.66
3	0.66	0.69	0.46	52	0.91	0.68	0.61	101	0.81	0.66	0.53	150	0.82	0.76	0.62	199	0.80	0.62	0.50
4	0.80	0.76	0.61	53	0.89	0.71	0.63	102	0.93	0.71	0.66	151	0.90	0.73	0.66	200	0.92	0.72	0.66
5	0.57	0.80	0.45	54	0.50	0.60	0.30	103	0.89	0.70	0.62	152	0.88	0.67	0.59	201	0.92	0.76	0.70
6	0.54	0.68	0.37	55	0.73	0.63	0.46	104	0.91	0.84	0.76	153	0.86	0.74	0.64	202	0.92	0.82	0.76
7	0.93	0.75	0.69	56	0.14	0.58	0.08	105	0.93	0.85	0.79	154	0.90	0.76	0.68	203	0.91	0.84	0.76
8	0.86	0.71	0.61	57	0.62	0.59	0.36	106	0.49	0.61	0.30	155	0.90	0.69	0.62	204	0.87	0.68	0.59
9	0.83	0.77	0.64	58	0.59	0.62	0.37	107	0.92	0.72	0.66	156	0.84	0.68	0.57	205	0.81	0.73	0.59
10	0.88	0.71	0.63	59	0.94	0.79	0.75	108	0.89	0.70	0.62	157	0.91	0.67	0.61	206	0.72	0.68	0.49
11	0.91	0.75	0.68	60	0.93	0.74	0.69	109	0.89	0.67	0.59	158	0.61	0.60	0.36	207	0.68	0.68	0.46
12	0.91	0.77	0.70	61	0.89	0.79	0.70	110	0.75	0.65	0.49	159	0.53	0.57	0.30	208	0.91	0.77	0.70
13	0.89	0.71	0.63	62	0.93	0.78	0.73	111	0.84	0.70	0.59	160	0.76	0.75	0.57	209	0.51	0.75	0.38
14	0.78	0.77	0.60	63	0.79	0.67	0.53	112	0.88	0.61	0.53	161	0.93	0.80	0.74	210	0.83	0.70	0.58
15	0.37	0.64	0.24	64	0.62	0.63	0.39	113	0.87	0.63	0.54	162	0.92	0.65	0.60	211	0.81	0.67	0.54
16	0.89	0.69	0.61	65	0.89	0.65	0.58	114	0.97	0.71	0.68	163	0.70	0.60	0.42	212	0.95	0.83	0.79
17	0.70	0.62	0.43	66	0.95	0.61	0.58	115	0.93	0.80	0.74	164	0.37	0.85	0.32	213	0.93	0.71	0.66
18	0.80	0.89	0.71	67	0.89	0.70	0.63	116	0.84	0.71	0.60	165	0.70	0.70	0.49	214	0.88	0.70	0.62
19	0.51	0.82	0.41	68	0.86	0.66	0.57	117	0.93	0.69	0.64	166	0.89	0.69	0.61	215	0.95	0.68	0.64
20	0.92	0.71	0.65	69	0.94	0.71	0.66	118	0.90	0.61	0.55	167	0.95	0.80	0.76	216	0.86	0.71	0.61
21	0.91	0.63	0.57	70	0.47	0.65	0.30	119	0.90	0.67	0.60	168	0.84	0.75	0.63	217	0.91	0.71	0.64
22	0.75	0.78	0.59	71	0.90	0.65	0.59	120	0.90	0.64	0.58	169	0.73	0.68	0.50	218	0.52	0.63	0.33
23	0.81	0.78	0.64	72	0.89	0.65	0.57	121	0.57	0.79	0.45	170	0.85	0.83	0.71	219	0.68	0.73	0.50
24	0.90	0.65	0.59	73	0.92	0.74	0.68	122	0.78	0.65	0.51	171	0.94	0.73	0.69	220	0.94	0.72	0.68
25	0.90	0.66	0.60	74	0.84	0.76	0.64	123	0.93	0.81	0.75	172	0.84	0.72	0.61	221	0.90	0.78	0.70

Firm#	TE	AE	EE	Firm#	TE	AE	EE	Firm#	TE	AE	EE	Firm#	TE	AE	EE	Firm#	TE	AE	EE
26	0.83	0.66	0.55	75	0.87	0.75	0.65	124	0.85	0.65	0.56	173	0.83	0.74	0.62	222	0.83	0.65	0.54
27	0.81	0.78	0.64	76	0.68	0.68	0.47	125	0.74	0.64	0.47	174	0.81	0.71	0.57	223	0.81	0.74	0.60
28	0.43	0.65	0.28	77	0.85	0.74	0.63	126	0.56	0.64	0.35	175	0.65	0.65	0.42	224	0.63	0.86	0.54
29	0.90	0.71	0.64	78	0.86	0.67	0.58	127	0.79	0.73	0.58	176	0.90	0.70	0.62	225	0.92	0.85	0.78
30	0.81	0.67	0.54	79	0.83	0.67	0.56	128	0.90	0.68	0.61	177	0.92	0.71	0.66	226	0.87	0.82	0.71
31	0.76	0.65	0.49	80	0.90	0.58	0.53	129	0.90	0.66	0.59	178	0.90	0.69	0.63	227	0.77	0.75	0.58
32	0.81	0.65	0.53	81	0.90	0.76	0.68	130	0.71	0.72	0.51	179	0.92	0.67	0.62	228	0.93	0.70	0.64
33	0.81	0.73	0.60	82	0.89	0.62	0.55	131	0.79	0.68	0.54	180	0.82	0.79	0.65	229	0.79	0.82	0.65
34	0.85	0.73	0.62	83	0.87	0.68	0.59	132	0.88	0.58	0.51	181	0.95	0.80	0.76	230	0.90	0.69	0.62
35	0.72	0.77	0.55	84	0.80	0.70	0.56	133	0.87	0.65	0.57	182	0.85	0.74	0.63				
36	0.94	0.66	0.63	85	0.92	0.74	0.68	134	0.85	0.60	0.51	183	0.65	0.68	0.44				
37	0.79	0.72	0.56	86	0.91	0.68	0.62	135	0.84	0.69	0.58	184	0.90	0.80	0.72				
38	0.90	0.66	0.60	87	0.92	0.64	0.58	136	0.90	0.68	0.61	185	0.89	0.70	0.62				
39	0.88	0.65	0.57	88	0.92	0.66	0.60	137	0.49	0.60	0.30	186	0.91	0.85	0.77				
40	0.87	0.71	0.62	89	0.89	0.70	0.63	138	0.79	0.74	0.58	187	0.89	0.70	0.63				
41	0.87	0.64	0.56	90	0.93	0.80	0.74	139	0.94	0.71	0.67	188	0.86	0.70	0.60				
42	0.85	0.74	0.63	91	0.60	0.68	0.41	140	0.93	0.65	0.60	189	0.48	0.67	0.33				
43	0.86	0.70	0.60	92	0.92	0.83	0.76	141	0.89	0.69	0.62	190	0.46	0.79	0.36				
44	0.94	0.71	0.67	93	0.94	0.71	0.67	142	0.90	0.67	0.60	191	0.84	0.82	0.69				
45	0.83	0.64	0.53	94	0.77	0.77	0.59	143	0.89	0.79	0.70	192	0.87	0.84	0.74				
46	0.90	0.73	0.65	95	0.64	0.63	0.40	144	0.85	0.70	0.59	193	0.91	0.75	0.68				
47	0.82	0.71	0.58	96	0.86	0.68	0.58	145	0.94	0.75	0.71	194	0.90	0.69	0.63				
48	0.89	0.66	0.59	97	0.83	0.65	0.54	146	0.84	0.68	0.57	195	0.86	0.68	0.59				
49	0.94	0.78	0.74	98	0.83	0.72	0.60	147	0.79	0.70	0.56	196	0.91	0.82	0.75				

Appendix 3: Results from estimation of inefficiency model

```
. regress EE Age Sex HHsize Off_farm Adult Prim Second CredAcc Exp Irrig, r

Linear regression                                      Number of obs =     230
                                                       F( 10,   219) =   10.10
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.3600
                                                       Root MSE      =  .09354
```

EE	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
Age	-.0017452	.0008574	-2.04	0.043	-.003435	-.0000554
Sex	.0045696	.0149015	0.31	0.759	-.0247991	.0339383
HHsize	-.0025478	.0019132	-1.33	0.184	-.0063184	.0012227
Off_farm	.0028655	.0139438	0.21	0.837	-.0246157	.0303468
Adult	.1105384	.0186929	5.91	0.000	.0736975	.1473794
Prim	.0572871	.0161396	3.55	0.000	.0254782	.089096
Second	.0601958	.0197796	3.04	0.003	.0212131	.0991785
CredAcc	-.0534628	.0140869	-3.80	0.000	-.081226	-.0256995
Exp	.0010474	.0008714	1.20	0.231	-.0006701	.0027648
Irrig	-.1285456	.0185615	-6.93	0.000	-.1651276	-.0919637
_cons	.6869177	.0396878	17.31	0.000	.6086988	.7651366

Appendix 4: Farmers' questionnaire for economic efficiency analysis for smallholder rice producers in Maramvya irrigated scheme, Burundi

Questionnaire Number : …………………………………………….

Date of interview : …………………………………………….

Interviewer's name : ……………………………………………..

A. Farmer's household characteristics

1. Farmer's name: …………………………… Tel …………… Block #: ………

2. Age: ……………………

3. Gender: 1 = Male [ ] 2 = Female [ ]

4. Marital status: 1 = Single [ ] 2 = Married [ ] 3 = Separated [ ] 4 = Widow [ ]

5. Level of education: 1 = No formal education [ ] 2 = Adult education [ ]

3 = Primary [ ] 4 = Secondary [ ] 5 = University [ ]

6. Household size and composition

Age group (years)	**Male**		**Female**		**Total**
	Attend School	**Not attending School**	**Attend School**	**Not attending School**	
0-5					
6-9					
10-15					
15-55					
> 55					
Total					

7. Years in rice farming: …………Years

Plot #	1	2	3	4	5	6	7	Total
Area (in hectares)								
Belongs to SRDI								
Rent from a person								
Total								

B. Farmer's land information for the last season

8. What size of land have you cultivated for the last season?

9. For the piece of land owned, how was it obtained? 1 = Inherited [ ] 2 = Bought [ ] 3 = Given by SRDI [ ] 4 = Accessed free land [ ]

10. If bought land, what was the price? …………………………BIF/hectare

11. If rented from SRDI or a person, how much paid per hectare (in cash)? ………BIF/hectare

12. If payment of rent was done in kind when harvest, how much Kg (or bags) per hectare? ……………….Kg (bags)

13. For the land rented from a person, if you decide to buy, how much would it cost? ………………….BIF/hectare

C. Inputs use information for the last season

(a) Labour

14. What is the average amount of labour used for various activities in rice farming (man-days per hectare) for last season?

Operations	**# of tasks**	**Amount of labour (in man-days)**	**Unitary cost (in BIF)**	**Total cost (in BIF)**
1. First tillage				
2. Second tillage preparation				
3. Leveling				
4. Nursery				
5. Transplanting				
6. First Weeding				
7. First fertilizer application				
8. Second weeding				
9. Second fertilizer application				
10. Harvesting				
11. Transport				
12. Drying				
13. Packaging				
14. Other activities				
Total				

15. Which factors do you think they greatly affect the use of labour in rice growing?

1 = High labour cost [ ] 2 = Labour unavailability during intense activities [ ]

3 = Unstable labour [ ] 4 = Other factors ……………………………

(b) Fertilizer

16. Did you use fertilizers during the last season? 1 = Yes [ ] 2 = No [ ]

17. If yes, what is the amount and cost?

Types of Fertilizer	Unit	Quantity	Unitary price (in BIF)	Total cost (in BIF)
NPK	Kg			
Urea	Kg			
Total	**Kg**			

18. If no, which factors do you think they greatly affect the use of fertilizer in rice growing?

1 = High cost [ ] 2 = Fertilizer unavailability [ ] 3 = Lack of capital to purchase fertilizer [ ] 4 = Unreliable output price [ ] 5 = Unreliable fertilizer supply [ ] 6 = Other reasons [ ]………………………………

(c) Seeds

19. What quantity of seeds did you use and what is the cost?

Types of seed	Unit	Quantity	Unitary price (in BIF)	Total cost (in BIF)
	Kg			

(d) Pesticides

20. What quantity of pesticides did you use and what is the cost?

Types of Pesticides	Unit	Quantity	Unitary price (in BIF)	Total cost (in BIF)

(e) Regularity of water for irrigation

21. For the last season, did you experience any shortage of water for irrigation?

1 = Yes [ ] 2 = No [ ]

22. At which extent the shortage of water was severe?

………………………………………………………………………………

………………………………………………………………………………

23. Other expenses related to production process (other than investment)

S/N	**Nature of expense**	**Amount (in BIF)**
1		
2		
3		
4		
5		
Total		

D. Production and off farm income

24. What quantity of paddy rice have you harvested during the last season?

Plot #	**Quantity**	**Unit (Kg or Bags)**	**Unitary price (in BIF)**	**Revenue(in BIF)**
1				
2				
3				
4				
5				
6				
7				
Total				

25. Given the size of land owned and input availability, do you set any target on yield to be achieved? 1 = Yes [ ] 2 = No [ ]

26. If yes, do you think that the targeted yield was achieved? 1 = Yes [ ] 2 = No [ ]

27. If no, what were the reasons to do not achieve the optimal yield?

1 = Bad weather [ ] 2 = Pests and diseases [ ] 3 = Low soil fertility [ ] 4 = Lack of fertilizers (low input use) 5 = Shortage of water for irrigation [ ] 6 = Shortage of labour [ ] 7 = Other reasons

………………………………………………………………

28. Apart from crop farming activities, do you have other activities bring income to your household? 1 = Yes [ ] 2 = No [ ]

29. What is your main activity? 1 = Rice farming [ ] 2 = Other activity [ ]

30. If yes, which activities and how much did you get from these activities during the last season?

S/N	Income generating activities	Daily Income (in BIF)	Average monthly income (in BIF)	Off-farm income for the last season (in BIF)
1				
2				
3				
4				
5				
Total				

E. Institutions and social inclusion

(a) Access to credit

31. Do you have access to credit facilities? 1 = Yes [ ] 2 = No [ ]

32. If yes, did you applied for credit for the last season? 1 = Yes [ ] 2 = No [ ]

33. If yes, what was the motive for demanding credit?

……………………………………………………………………………………………

(b) Extension service

34. Do you have access to extension services? 1= Yes [ ] 2 = No [ ]

35. If yes, how many times did you meet the extension agent during the last season?

……………………………………………………………………………………………

36. What services do you benefit from extension agent?

……………………………………………………………………………………………

THANK YOU VERY MUCH FOR YOUR COOPERATION!

Appendix 5: Raw data for rice production in Maramvya irrigated scheme

Firm #	Paddy Produced (kg)	Land (ha)	Land Cost (BIF)	Labour (man-days)	Lab Cost (BIF)	Seed (kg)	Sex 1=male 2=female	Age (years)	Exp (years)	Education 1=illiteracy 2=adult educ 3=primary 4=secondary	Hhsize (# of persons)	Off-Farm 1=yes 2=non	CredAcc 1=yes 2=non	Irrig 1=yes 2=non
1	2500	0.5	96000	200	3702	30	1	66	40	3	6	2	1	2
2	3200	0.75	144000	300	3924	75	1	67	32	3	9	2	1	2
3	770	0.2	19200	80	4086	25	2	46	19	3	4	1	1	1
4	1200	0.25	48000	100	3720	15	1	33	10	1	7	2	1	2
5	700	0.25	48000	90	4641	13	2	45	10	1	8	2	1	2
6	400	0.12	11520	49	3750	12.5	1	42	5	1	11	2	1	1
7	1300	0.22	20640	86	3954	22.5	2	70	30	1	3	2	1	2
8	1100	0.21	19680	82	3720	30	2	63	30	1	6	2	1	2
9	1300	0.26	49920	104	4320	35	2	70	33	3	2	2	1	2
10	2500	0.45	86400	180	4278	50	1	36	21	3	8	1	1	2
11	1000	0.14	13440	56	4467	7.5	1	77	30	2	4	2	1	2
12	800	0.11	10560	42	5799	7.5	1	55	30	1	9	2	1	2
13	2700	0.45	86400	180	4410	50	2	45	34	1	8	2	1	2
14	1400	0.3	57600	120	3303	15	1	53	30	3	14	1	1	2
15	1000	0.45	86400	200	3111	30	2	35	20	3	8	2	1	1
16	3000	0.5	96000	200	4554	45	1	45	20	3	10	1	1	2
17	900	0.21	20160	84	4173	32.5	1	69	20	3	5	2	1	2
18	1300	0.42	80640	98	3705	25	2	36	6	3	7	1	1	2
19	830	0.42	80640	84	3960	25	1	36	20	3	10	1	1	1
20	2800	0.43	82560	170	4107	30	1	45	15	2	9	2	1	2
21	800	0.15	14400	60	5658	35	1	27	14	4	6	2	1	2
22	400	0.11	10560	44	4257	15	1	73	40	3	3	2	1	2
23	800	0.19	18240	76	2895	20	2	35	5	3	7	1	2	2
24	1300	0.19	18240	76	3555	45	1	67	34	3	10	2	1	2
25	1400	0.22	21120	90	4746	27.5	1	55	20	1	4	2	1	2
26	1050	0.22	21120	88	4050	35	1	46	30	3	9	1	1	2
27	1000	0.25	48000	100	4650	45	2	72	34	2	7	2	1	2
28	400	0.17	16320	68	3186	30	1	85	43	1	8	2	1	2

Firm #	Paddy Produced (kg)	Land (ha)	Land Cost (BIF)	Labour (man-days)	Lab Cost (BIF)	Seed (kg)	Sex 1=male 2=female	Age (years)	Exp (years)	Education 1=illiteracy 2=adult educ 3=primary 4=secondary	Hhsize (# of persons)	Off-Farm 1=yes 2=non	CredAcc 1=yes 2=non	Irrig 1=yes 2=non
29	2600	0.38	72960	152	4188	30	1	55	40	1	8	2	1	2
30	1100	0.22	21120	102.7	2928	30	2	46	32	1	9	2	1	2
31	1100	0.2	19200	80	3672	17.5	1	49	27	3	8	1	1	1
32	2500	0.55	105600	220	4770	60	1	55	37	3	7	2	1	1
33	1280	0.26	49920	141.3	3114	25	1	46	23	3	8	2	1	2
34	800	0.15	13920	77.33	3300	12.5	2	46	23	3	8	2	1	2
35	450	0.12	11040	46	3588	17.5	2	56	34	1	10	2	1	2
36	2000	0.22	21120	88	5832	27	1	53	39	3	12	2	1	2
37	1450	0.3	57600	120	3576	30	1	55	25	1	7	2	1	2
38	1500	0.21	20160	98	4206	25	1	50	24	3	6	1	1	2
39	2500	0.45	86400	240	3579	40	1	50	20	2	13	2	1	2
40	1000	0.2	19200	80	3942	25	1	62	22	3	8	2	1	2
41	1200	0.2	19200	93.33	4155	30	1	52	30	3	13	2	1	2
42	880	0.15	14400	60	3999	15	2	70	35	1	5	2	1	2
43	770	0.15	14400	60	4074	15	1	33	17	3	8	2	1	2
44	3960	0.5	96000	200	4182	50	1	33	17	3	8	2	1	2
45	2560	0.45	86400	210	4083	60	1	65	25	1	2	2	1	2
46	2500	0.36	69120	168	3720	45	2	38	16	1	13	1	1	2
47	1540	0.29	55680	116	4317	40	1	80	40	3	16	2	1	2
48	1430	0.2	19200	80	4860	30	2	67	6	1	16	2	1	2
49	2400	0.32	61440	126	4701	15	1	55	42	2	8	2	1	2
50	2500	0.45	86400	180	3672	50	1	37	16	1	8	2	1	2
51	2100	0.35	67200	140	4233	50	2	40	24	3	9	2	1	2
52	1000	0.15	14400	70	4626	30	1	48	14	3	4	2	1	2
53	2000	0.3	57600	140	3375	60	2	47	17	3	4	2	1	2
54	1100	0.34	65280	181.3	4491	40	1	61	42	1	12	2	1	2
55	945	0.18	16800	93.33	3255	15	1	55	33	3	7	2	1	1
56	350	0.41	78720	191.3	2718	30	1	82	41	1	7	2	1	1
57	900	0.22	21120	102.7	2913	40	1	50	7	1	10	2	1	1
58	810	0.21	20160	112	3069	20	1	56	13	3	5	2	2	1

Firm #	Paddy Produced (kg)	Land (ha)	Land Cost (BIF)	Labour (man-days)	Lab Cost (BIF)	Seed (kg)	Sex 1=male 2=female	Age (years)	Exp (years)	Education 1=illiteracy 2=adult educ 3=primary 4=secondary	Hhsize (# of persons)	Off-Farm 1=yes 2=non	CredAcc 1=yes 2=non	Irrig 1=yes 2=non
59	1000	0.14	13440	56	3636	19	2	43	3	4	7	1	2	2
60	2000	0.25	48000	100	5334	60	2	69	40	2	9	2	1	2
61	1400	0.25	48000	100	3990	50	2	35	9	3	8	2	1	2
62	700	0.09	8640	38	4008	17.5	1	40	30	1	9	2	1	2
63	900	0.2	19200	93.33	3504	21	1	45	10	3	7	2	1	2
64	600	0.17	15840	77	3114	32.5	1	35	8	3	7	2	1	1
65	1300	0.2	19200	93.33	4434	25	1	33	8	1	6	2	2	2
66	4800	0.5	96000	266.7	4185	100	2	35	13	4	8	1	1	2
67	1200	0.23	21600	90	3780	25	1	49	35	3	10	2	1	2
68	1200	0.23	21600	105	3567	22.5	1	40	30	1	10	2	1	2
69	1750	0.19	18240	74	4557	25	2	50	30	1	8	2	1	2
70	1000	0.4	76800	160	3597	60	1	48	12	3	15	1	1	2
71	1500	0.2	19200	106.7	3801	25	2	40	20	3	8	2	1	2
72	1320	0.23	21600	105	3765	30	1	34	20	1	9	2	1	2
73	2000	0.34	64320	134	3954	35	2	42	20	4	11	1	1	2
74	1540	0.25	48000	116.7	3534	25	2	52	20	1	8	1	1	2
75	1680	0.25	48000	116.7	3534	25	2	52	24	1	8	1	1	2
76	650	0.16	15360	74.67	4053	20	2	49	32	3	7	2	1	2
77	600	0.11	10560	44	5295	22.5	2	58	28	1	4	2	1	2
78	3000	0.5	96000	233.3	3636	60	2	75	40	1	3	2	1	2
79	750	0.14	13440	65.33	4716	27.5	1	49	28	3	13	1	1	2
80	3150	0.51	97920	272	4053	110	1	63	38	4	7	1	1	1
81	1760	0.25	48000	116.7	3975	25	2	40	20	1	8	2	1	2
82	3000	0.5	96000	266.7	3120	50	2	46	25	4	10	2	1	2
83	2700	0.5	96000	200	3708	60	1	52	35	3	10	2	1	2
84	700	0.14	13440	65.33	3795	20	2	41	20	1	20	2	1	2
85	2310	0.26	49920	121.3	4644	15	1	45	25	3	19	1	1	2
86	1260	0.21	20160	84	5202	25	1	36	24	3	11	2	1	2
87	1900	0.24	23040	112	3951	25	1	55	13	3	8	2	1	2
88	1800	0.25	23520	98	4212	25	1	55	13	3	8	2	1	2

Firm #	Paddy Produced (kg)	Land (ha)	Land Cost (BIF)	Labour (man-days)	Lab Cost (BIF)	Seed (kg)	Sex 1=male 2=female	Age (years)	Exp (years)	Education 1=illiteracy 2=adult educ 3=primary 4=secondary	Hhsize (# of persons)	Off-Farm 1=yes 2=non	CredAcc 1=yes 2=non	Irrig 1=yes 2=non
89	800	0.16	14880	72.33	3750	20	2	25	7	4	5	1	1	2
90	770	0.11	10560	51.33	3966	10	1	39	22	3	8	2	1	2
91	660	0.21	20160	84	3318	30	2	60	16	1	7	2	1	2
92	1680	0.28	53760	110	3705	20	1	58	40	3	8	2	1	2
93	1500	0.2	19200	80	4122	25	1	49	20	1	10	2	1	2
94	600	0.13	12000	50	4242	10	2	65	40	1	1	2	1	2
95	900	0.22	21120	102.7	3486	30	2	50	20	1	11	1	1	2
96	2100	0.38	72000	175	4173	40	1	48	15	3	7	2	1	2
97	900	0.18	16800	81.67	4908	20	1	48	20	3	7	2	1	2
98	1000	0.2	19200	80	3711	30	2	60	40	1	5	2	2	2
99	1300	0.2	19200	93.33	3780	15	1	46	15	3	7	1	1	2
100	1200	0.4	76800	186.7	3543	70	2	65	43	1	7	2	1	1
101	1000	0.2	19200	80	4473	25	1	52	30	3	8	2	1	1
102	1650	0.22	20640	86	4695	15	1	39	19	3	9	1	1	2
103	1100	0.16	15360	64	4578	15	1	52	10	1	5	2	1	1
104	550	0.1	9600	46.67	3819	8.5	1	37	10	3	7	2	2	2
105	575	0.09	8160	34	3423	13	1	47	20	3	11	2	1	2
106	750	0.24	23040	112	4260	17	2	70	41	1	4	2	1	2
107	1300	0.17	16320	68	4797	19	1	77	47	3	4	2	1	2
108	1100	0.18	16800	81.67	4185	25	2	53	35	1	8	2	1	2
109	770	0.16	15360	64	5085	25	1	30	7	4	6	1	1	2
110	840	0.22	21120	86	4251	30	1	30	10	1	6	2	1	2
111	1046	0.22	21120	86	3264	25	1	42	22	3	10	1	1	2
112	3150	0.48	92160	253.3	4008	70	1	45	2	1	10	2	1	2
113	2993	0.44	84480	232	3732	50	1	71	15	1	8	2	1	2
114	4320	0.4	76800	160	3492	45	1	23	5	4	13	2	1	2
115	1840	0.28	53760	112	4632	30	1	54	35	3	8	2	1	2
116	1785	0.3	57600	160	4020	25	2	44	15	3	11	2	1	2
117	1680	0.23	21600	90	5136	20	1	47	20	3	15	2	1	2
118	1500	0.21	20160	112	4791	15	1	48	23	2	13	2	1	1

Firm #	Paddy Produced (kg)	Land (ha)	Land Cost (BIF)	Labour (man-days)	Lab Cost (BIF)	Seed (kg)	Sex 1=male 2=female	Age (years)	Exp (years)	Education 1=illiteracy 2=adult educ 3=primary 4=secondary	Hhsize (# of persons)	Off-Farm 1=yes 2=non	CredAcc 1=yes 2=non	Irrig 1=yes 2=non
119	800	0.14	13440	56	5451	32.5	1	39	13	4	11	1	2	1
120	1520	0.24	23040	96	4746	15	1	39	13	4	11	1	2	1
121	780	0.27	51840	108	3567	25	2	40	30	1	8	2	2	1
122	2415	0.52	99840	278.7	3075	50	2	63	43	1	7	2	1	2
123	690	0.11	10080	49	4737	10	1	35	13	3	6	2	2	2
124	1300	0.2	19200	106.7	3777	15	2	50	35	1	7	2	1	2
125	880	0.2	19200	93.33	4101	20	1	27	3	1	9	2	2	2
126	1600	0.51	96960	235.7	3558	60	2	65	42	1	6	2	1	1
127	630	0.13	12480	52	4461	15	2	38	20	3	10	2	1	2
128	2415	0.34	64320	156.3	4248	40	1	50	30	1	9	2	1	1
129	2940	0.44	83520	203	3966	50	1	50	30	1	9	2	1	1
130	1430	0.29	55680	137.7	3867	35	2	70	27	1	2	2	2	1
131	960	0.16	15360	64	5079	15	2	43	25	1	14	2	2	1
132	1650	0.22	21120	117.3	4116	25	1	50	35	1	9	2	1	2
133	3000	0.5	96000	266.7	3780	60	1	62	29	3	9	2	2	2
134	1200	0.18	17280	81.67	5664	30	1	53	36	1	9	2	1	1
135	1900	0.33	63360	154	3492	60	1	43	7	1	8	2	2	1
136	900	0.16	15360	74.67	5721	30	1	31	27	1	6	2	2	2
137	600	0.19	18240	88.67	3579	30	1	47	30	1	10	2	2	1
138	720	0.17	16320	67	4587	20	2	50	27	1	9	2	2	2
139	1380	0.23	21600	90	4362	30	1	53	35	2	11	2	1	2
140	1440	0.23	22080	92	5124	15	1	40	15	4	13	1	1	2
141	1100	0.18	16800	70	4644	25	1	62	37	3	12	1	1	2
142	1430	0.23	21600	90	4143	30	1	62	37	3	12	1	1	2
143	1540	0.25	48000	100	3111	30	1	62	37	3	12	1	1	2
144	2700	0.47	90240	188	4386	30	2	37	17	1	10	1	1	2
145	1920	0.23	21600	90	3963	20	1	50	20	3	9	1	2	2
146	2310	0.4	76800	186.7	3891	60	2	70	32	3	12	2	1	1
147	1980	0.44	84480	176	4122	60	1	52	24	3	9	1	2	1
148	1320	0.21	20160	84	3846	20	1	62	35	3	8	2	2	2

Firm #	Paddy Produced (kg)	Land (ha)	Land Cost (BIF)	Labour (man-days)	Lab Cost (BIF)	Seed (kg)	Sex 1=male 2=female	Age (years)	Exp (years)	Education 1=illiteracy 2=adult educ 3=primary 4=secondary	Hhsize (# of persons)	Off-Farm 1=yes 2=non	CredAcc 1=yes 2=non	Irrig 1=yes 2=non
149	945	0.24	22560	94	3831	35	2	70	35	1	6	2	2	2
150	3000	0.92	176640	184	4137	40	1	55	32	3	7	2	1	2
151	2100	0.28	53760	130.7	4071	30	1	55	32	3	7	1	1	2
152	2800	0.45	86400	180	4914	60	1	62	29	1	10	2	2	2
153	810	0.15	14400	60	4809	15	1	62	35	3	8	1	1	2
154	900	0.17	16320	68	3732	15	1	50	30	2	8	1	1	2
155	1260	0.24	23040	96	3918	30	1	50	30	2	8	1	1	2
156	900	0.18	17280	72	5436	15	1	50	30	2	8	1	1	1
157	900	0.16	15360	74.67	4674	15	1	47	32	4	11	1	1	2
158	1800	0.43	82560	172	4353	50	1	54	26	1	20	2	1	1
159	800	0.22	21120	102.7	3864	30	1	54	26	1	20	2	1	1
160	1155	0.25	48000	100	4452	25	1	39	20	3	10	1	1	1
161	1000	0.19	18240	72	4122	20	1	50	40	3	3	2	2	2
162	1785	0.23	22080	92	4998	25	1	72	47	2	8	2	1	1
163	820	0.18	16800	93.33	3690	27.5	1	72	47	2	8	2	1	1
164	500	0.38	72960	74	3942	25	1	72	34	1	7	2	2	1
165	735	0.24	23040	96	3120	30	1	37	25	1	8	2	2	2
166	1200	0.21	20160	84	4962	25	1	22	4	3	1	1	1	2
167	2565	0.35	67200	140	4116	30	1	48	20	2	8	2	2	2
168	1890	0.33	62400	130	3483	25	2	62	35	1	7	2	1	2
169	935	0.24	22560	94	4059	30	2	50	22	1	7	2	2	1
170	990	0.25	48000	100	4605	32	2	62	47	1	10	2	2	2
171	3000	0.38	72000	150	4521	40	1	50	30	3	10	2	1	2
172	900	0.2	19200	80	3702	25	1	60	47	3	8	1	1	2
173	1400	0.3	57600	120	3984	40	1	58	32	3	12	2	1	2
174	682	0.16	15360	64	4485	25	1	58	32	3	12	2	1	2
175	735	0.23	21600	90	4260	30	1	58	32	3	12	2	1	2
176	1300	0.23	21600	90	3744	25	1	51	17	3	6	2	1	2
177	3000	0.45	86400	180	3942	60	1	51	17	3	6	2	1	2
178	2530	0.38	72000	150	3870	50	2	60	25	2	5	2	1	2

Firm #	Paddy Produced (kg)	Land (ha)	Land Cost (BIF)	Labour (man-days)	Lab Cost (BIF)	Seed (kg)	Sex 1=male 2=female	Age (years)	Exp (years)	Education 1=illiteracy 2=adult educ 3=primary 4=secondary	Hhsize (# of persons)	Off-Farm 1=yes 2=non	CredAcc 1=yes 2=non	Irrig 1=yes 2=non
179	1365	0.2	19200	80	5256	25	1	36	15	1	12	2	1	2
180	450	0.09	8640	36	3945	15	1	54	20	3	12	1	2	2
181	3150	0.37	71040	148	4035	45	1	54	20	3	12	1	2	2
182	1000	0.2	19200	80	3777	20	2	35	25	3	9	2	2	1
183	1650	0.39	74880	156	3675	45	2	45	25	1	7	2	2	1
184	1800	0.32	61440	100	4056	30	1	51	32	1	10	2	1	2
185	2500	0.4	76800	160	4116	30	1	51	32	1	10	2	1	2
186	577	0.09	8640	36	4320	10.5	2	53	12	2	8	1	2	2
187	1000	0.18	16800	70	4632	30	1	35	11	3	8	1	1	2
188	2300	0.37	71040	148	4707	40	1	53	35	3	10	2	2	1
189	600	0.23	21600	90	3945	25	2	61	17	1	10	1	2	2
190	500	0.25	48000	100	3279	40	2	45	32	3	10	1	1	2
191	1150	0.26	49920	121.3	3399	25	2	53	40	1	7	2	2	2
192	1400	0.25	48000	100	3696	20	2	45	31	3	4	2	2	2
193	990	0.17	15840	66	3681	20	1	43	29	3	7	2	1	2
194	3300	0.5	96000	233.3	3450	40	1	67	47	1	8	2	2	2
195	1400	0.21	20160	98	4197	15	2	60	37	1	10	2	2	1
196	600	0.1	9600	40	5139	15	2	40	20	2	11	1	2	2
197	800	0.2	19200	80	3258	30	1	60	27	2	7	2	1	2
198	800	0.16	15360	64	4125	25	2	69	47	3	6	2	2	2
199	1680	0.35	66240	161	3774	50	1	68	23	4	7	2	1	1
200	2860	0.42	79680	166	4230	60	1	43	15	3	12	1	2	2
201	2420	0.35	67200	140	4284	50	1	43	15	3	12	1	2	2
202	1785	0.26	49920	104	4761	35	2	70	47	1	3	2	2	2
203	1540	0.27	51840	108	4359	30	2	32	15	3	11	2	2	2
204	1800	0.4	76800	160	4080	40	1	58	35	4	10	2	1	2
205	700	0.18	16800	70	4233	25	2	25	6	3	8	2	1	2
206	1980	0.45	86400	180	3591	50	2	50	27	1	11	1	1	2
207	1680	0.4	76800	160	3537	50	2	50	27	1	11	1	1	2
208	1100	0.2	18720	78	4746	35	2	50	35	3	6	1	2	2

Firm #	Paddy Produced (kg)	Land (ha)	Land Cost (BIF)	Labour (man-days)	Lab Cost (BIF)	Seed (kg)	Sex 1=male 2=female	Age (years)	Exp (years)	Education 1=illiteracy 2=adult educ 3=primary 4=secondary	Hhsize (# of persons)	Off-Farm 1=yes 2=non	CredAcc 1=yes 2=non	Irrig 1=yes 2=non
209	800	0.32	61440	128	3414	40	2	45	20	1	5	2	2	2
210	1100	0.23	21600	90	4170	35	2	60	35	1	2	2	2	1
211	1210	0.24	23040	96	3693	25	1	45	20	3	9	1	1	1
212	1300	0.15	14400	60	4131	15	1	68	24	3	3	1	2	2
213	1500	0.21	20160	84	5253	20	1	62	35	1	4	2	2	2
214	1000	0.18	17280	72	5289	25	1	58	29	1	5	2	2	2
215	2200	0.21	19680	82	5778	25	1	25	15	3	7	1	1	2
216	1000	0.19	17760	74	4713	20	1	58	29	1	5	2	2	2
217	1210	0.18	16800	70	4884	30	1	65	35	3	6	2	2	2
218	700	0.2	19200	80	4275	15	1	68	47	1	8	2	2	1
219	650	0.18	17280	72	4617	17	2	62	47	1	7	2	2	2
220	3080	0.35	67200	163.3	3702	30	1	45	20	3	7	2	1	2
221	2200	0.36	69120	144	4173	30	1	47	29	3	10	1	2	2
222	2300	0.45	86400	210	3750	60	1	35	15	3	10	1	1	2
223	600	0.15	14400	60	3876	30	1	51	17	3	11	2	2	2
224	350	0.12	11520	48	2787	10	2	54	33	3	3	2	2	2
225	660	0.1	9120	38	3840	14	2	56	10	3	10	1	1	2
226	1420	0.25	48000	100	5055	20	2	54	32	3	10	2	2	2
227	1300	0.27	50880	106	3816	30	1	57	30	1	10	2	2	1
228	1575	0.23	21600	90	5076	25	1	42	22	3	6	2	2	2
229	900	0.26	49920	104	3702	35	2	45	24	2	6	2	2	2
230	960	0.22	20640	86	3912	20	1	30	4	4	9	2	2	2