PERFORMANCE OF FISH SMOKING KILNS AND ASSOCIATED IMPACT ON FOREST RESOURCE: CASE STUDY OF LAKE CHILWA BASIN

MASTER OF ARTS (ECONOMICS) THESIS

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UNIVERSITY OF MALAWI

CHANCELLOR COLLEGE

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Master of Arts (Economics) Thesis

By

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DECLARATION

I, the undersigned, hereby declare that this thesis is my original work which has not been submitted to any other institution for similar purposes. Where other people's work has been used acknowledgements have been made.

DAVIES MADALITSO LUHANGA

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Signature

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Date

CERTIFICATE OF APPROVAL

The undersigned certify that this thesis represents the student's own work and effort and has been submitted with our approval.

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DEDICATION

To my dearest daughter, Jacqueline

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ABSTRACT

The study investigates the performance of the traditional and improved fish smoking kilns in the Lake Chilwa basin using a stochastic production frontier. The kiln performance is measured through its efficiency in utilising inputs (firewood and labour) for an output (Smoked fish). Since fish smoking depends on the forest resource, the study also endeavours to estimate the extent of deforestation that would be avoided by using a more efficient kiln type over a specific period of time. The study uses primary data that was collected from fish smokers through field experiments and semi-structured questionnaires.

The study shows that transcendental logarithmic (Translog) and Cobb-Douglas stochastic frontiers best represent data captured from traditional and improved kilns respectively. In addition, the study indicates no evidence of technical inefficiencies in both traditional and improved fish smoking kiln models. This implies that production functions for both traditional and improved fish smoking kilns have normal errors. The study further reveals that there is no significant difference in the mean technical efficiency levels between traditional and improved fish smoking kilns.

The empirical results indicate that there is no difference in the amount of firewood used to smoke a given quantity of fresh fish between traditional and improved kilns. Consequently, there is no evidence of deforestation avoided by using either of the smoking methods.

The study has however showed that traditional kilns use more labour than improved kilns to smoke a given quantity of fresh fish. Consequently, use of the improved kilns can divert human resources to other productive ventures.

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LIST OF ABBREVIATIONS AND ACRONYMS

AE	Allocative Efficiency
CD	Cobb-Douglas
CES	Constant Elasticity of Substitution
COLS	Corrected Ordinary Least Squares
DEA	Data Envelopment Analysis
EAD	Environmental Affairs Department
EE	Economic Efficiency
Ha	Hectares
Hrs	Hours
IAA	Integrated Aquaculture-Agriculture
Kg	Kilogram
Km^2	Square kilometre
LCBCCAP	Lake Chilwa Basin Climate Change and Adaptation Programme
LR	Log-likelihood
M^3	Cubic metres
MLE	Maximum Likelihood Estimation
OLS	Ordinary Least Squares
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency
Translog	Transcendantal Logarithm

CHAPTER 1

INTRODUCTION

1.1 Background

The Lake Chilwa basin is one of the most important wetlands in Malawi. It is located in the south-eastern part of the country. The basin stretches along three districts, namely; Phalombe, Zomba and Machinga. It is bounded by Zomba mountain in the west, Mulanje massif to the south and Chikala hills to the north. Lake Chilwa is the second largest lake in the country and the twelfth largest natural lake in Africa. It is an enclosed lake with a surrounding reed belt widest on the north and north-east side and a seasonally flooded plain. Its waters are saline with open water area of around 678 km^2. It is surrounded by an average of 600 km^2 of Typha swamps, 390 km^2 of marshes and 580 km^2 of seasonally inundated grassland of floodplain (Njaya, 2001). These vary with the level of the lake each year. The basin directly supports 1.5 million people who live within the basin and beyond its boundaries (Chiwaula and Chaweza, 2010). It provides a number of opportunities for livelihood enhancement such as fish processing, fishing, farming, hunting and other natural resource based livelihood activities.

Fish smoking is one of the livelihood activities directly supported within the basin and is the most common method of preserving the lake's fresh fish (tilapia and catfish). Fish smoking elongates shelf life of fish through lowering moisture content. Most customers for Lake Chilwa fish prefer smoked tilapia and catfish to sun-air dried forms (WorldFish Center, 2010). However, fish smoking activity creates demand on firewood thereby exacerbating the pressure on the forest resource base. Both indigenous and exotic species of wood are used for fish smoking. Approximately 8,000 metric tonnes of firewood was being used for fish smoking annually in Malawi (The Malawi German Fisheries and Aquaculture Development project, 1986-94). In addition, Lake Chilwa Basin Climate Change and Adaptation Project (LCBCCAP) qualitative data obtained from fishers at Mposa during the hotspot identification exercise in 2010 indicated that each fish processor at the beach used an average of three cubic meters of firewood per day to smoke fish during peak production period (WorldFish Center, 2010). Evidently, fish smoking is one of the major contributors of deforestation in the country, though less documented.

Over the years, fish smoking has been done using traditional methods which range from open fires, drums to mobile metal kilns. Some fish processors still use traditional methods despite their high use of firewood. In an effort to minimise the levels of deforestation, GTZ through the Malawi-German Fisheries and Aquaculture Development Project introduced improved fish-smoking kilns to fish processors in 1987. However, the fish smokers did not sustain the technology due to its high input costs, in particular the wire mesh that is used in constructing smoking trays. A breakthrough was achieved in 2010 when the WorldFish Center re-introduced the improved fish smoking kilns at Mposa, Kachulu and Swang'oma beaches under the LCBCCAP. The technology has since been widely adopted among fish smokers. The oven of improved kilns has a combustion chamber where heat and smoke are generated using firewood and a smoking unit made up of a set of 5-10 trays each with wire mesh at the bottom and a wooden frame. Construction materials for the combustion chamber are usually bricks/stones and cement/mud.

Fish smoking is normally done by fish traders who buy fresh fish from fishermen. They then rent fish smoking kilns from local entrepreneurs and the firewood used for smoking is bought from the local firewood sellers around fish processing areas. Local entrepreneurs construct improved kilns in some shelters which also provide housing for the fish smokers. The scenario is different at Mposa in Machinga where temporary shacks (*zimbowera*) are constructed on water. Fish smokers reside and smoke the fish from the temporary shacks. Mobile metal kilns are the most commonly used kilns in the temporary shacks. Smoked fish is brought to the dock either by the smokers themselves or other intermediate traders who buy smoked fish from the temporary shacks.

1.2 Statement of the Problem

Following the adoption of improved fish smoking kilns, fish traders/smokers in the Lake Chilwa Basin have observed a reduction in the amount of firewood required to smoke a given amount of fish (WorldFish Center, 2010). Consequently, a certain amount of deforestation is being avoided by using improved kilns.

It is however not clear which method between the two available ones i.e. traditional and improved kilns is more efficient in terms of input usage since firewood is just one of the inputs. There are other inputs required in fish smoking like labour which also need to be estimated in order to establish the input use differentials since they may have impact on forestation. There has been no study so far that has established this relationship. This study therefore, aims at closing this gap by estimating the level of technical efficiency of the fish smoking kilns.

1.3 Objectives of the Study

The main objective of this study is to investigate the technical efficiency of improved and traditional fish smoking kilns and the estimated deforestation avoided by consistently using the efficient kiln. In order to achieve all this, the study specifically attempts:

1. To determine whether there are differences in the mean technical efficiency of improved kilns and traditional methods of fish smoking; and
2. To estimate the extent of deforestation that would be avoided in a year by using a more efficient kiln.

1.4 Study Hypothesis

The study tests the following null hypotheses:

1. There is no difference in mean technical efficiency levels between improved kilns and the traditional methods of fish smoking.
2. The rate of deforestation is not different between the two fish smoking methods.

1.5 Significance of the Study

The study on comparative performance of the two methods of smoking fish (traditional and improved smoking kilns) is important as it forms the basis for adoption of improved kilns among fish smokers within the basin. The performance of the kilns is examined based on use of inputs for smoking fish, namely labour and firewood. In a resource constrained country like Malawi, the importance of using inputs efficiently needs not to be overemphasized. The understanding of the input use differentials in fish smoking is essential in forest resource management as well as diverting human capital to other economic ventures.

1.6 Organization of the Study

The rest of the thesis is organised as follows: Chapter 2 reviews the available literature. Specifically it looks at literature on deforestation in Malawi. This is followed by a review on estimation method of stochastic production functions and technical efficiency measures. The last part of the chapter focuses on existing empirical literature relating to estimation of stochastic production frontier and technical efficiency. Chapter 3 presents the methodology for the study and it is in this chapter that the model is specified. Chapter 4 presents and discusses findings of the study while conclusions and policy recommendations are provided in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The purpose of this chapter is to review the literature on deforestation issues in Malawi, the theoretical literature with respect to estimation of stochastic production function and technical efficiencies in the fisheries industry. Specifically, Section 2.1 focuses on the deforestation issues in Malawi. This will be followed by a review on estimation of stochastic production functions and technical efficiency measures. The last part of this chapter focuses on existing empirical literature relating to estimation of stochastic production frontier and technical efficiency.

2.1 Deforestation Issues in Malawi

Forest resources are vital to Malawi as a source of energy to a large percentage of the population. They also help in maintaining biodiversity in both terrestrial and aquatic environments, and stabilise catchments which in turn minimises siltation of lakes and rivers. The previously vast forest resources have been considerably reduced from 4.4 million hectares to around 1.9 million between 1973 and 1998 (Government of Malawi, 1998). The increasing demand for land for crop production and growing demand for wood-fuel makes sustainable management of the forest resources an almost impossible task. In addition, the increasing incidences of wildfires in forest plantations and reserves have resulted in losses running into millions of dollars (Government of Malawi, 1998). Government of Malawi (1998) also documents an increased demand for wood products, mainly fuelwood due to increased population. The increase in population has resulted in an increase in demand for services and products offered by the forestry. As population pressure increases, the capacity of the forest resource to supply products and services in a sustainable manner is threatened.

Uncontrolled tree felling for fuelwood for curing tobacco in the smallholder and estate sectors is among the main causes of deforestation in the country. Government of Malawi (1998) reported that tobacco farmers in Mangochi District, at the outskirts of the Namizimu Forest, had illegally entered into inaccessible parts of the forest and decimated large tracts of the natural Miombo trees for use in curing tobacco. Similar occurrences are common in parts of Mchinji, Mzimba and Kasungu Districts.

Shortage of land in the country, has also led to a lot of forest clearing to accommodate the demands for farm land. In many cases, the resultant deforestation has been due to the collapse of traditional controls over the allocation of land. Furthermore, unscrupulous business people lure employees and local people to cut trees illegally on customary lands for commercial farming. The new owners of the land indiscriminately cut the trees and sell them as firewood and charcoal to both urban and farm people. This has even resulted in the breaking of legal controls over trafficking of forest products, exacerbated by inadequate supervision by law enforcers such as forest guards (Government of Malawi, 2002).

There is an increasing opportunistic trade in scarce resources; and firewood has become a commodity. In the customary land areas, trees are being cut for brick burning, lime firing and other businesses. Legislation that would control deforestation from these activities is available but not adequately enforced. Likewise, the royalty for indigenous trees has remained low (Government of Malawi, 2010).

It should be noted that the Government of Malawi (1998) listed the main causes of deforestation in the country with no mention of the deforestation due to fish smoking. Thus this study will endeavour to document the extent of deforestation caused by Lake Chilwa fish smokers.

2.2 Theoretical Literature on Efficiency

2.2.1 The Concept of Technical Efficiency

Following Farrell (1957) and other scholars, a firm can illustrate its economic efficiency through two measures; namely technical efficiency and allocative efficiency. The technical efficiency represents the ability to obtain the maximum potential firm performance (output) from a given set of inputs. In other words, it is the conversion of physical inputs into outputs relative to the best practice. In contrast, allocative efficiency refers to whether inputs, for a given output and set prices, are chosen to minimise cost of production; assuming that the firm being examined is already fully technically efficient. It shows the availability of the producer to combine inputs and outputs in optimal proportions given prevailing prices and technologies. Allocative and technical efficiency combine to provide an overall economic efficiency measure (i.e. product of the two). For this study, however, our emphasis will be on technical efficiency.

The three concepts of efficiency are best depicted graphically, as in Figure 2.1 which illustrates a firm that uses two inputs, (x_1 and x_2) to produce a single output, (y), under the assumption of constant returns to scale[1].

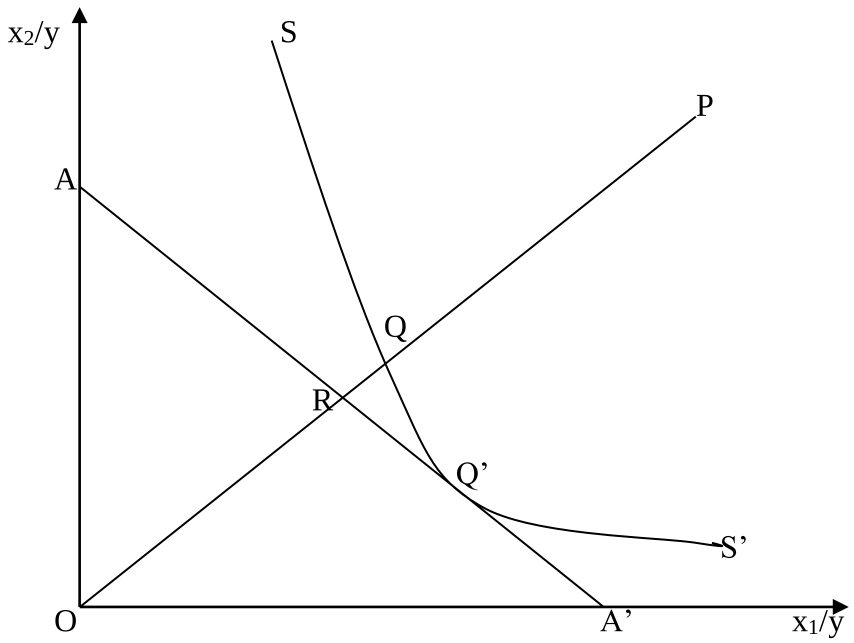

Figure 2.1: **Technical, Allocative and Economic Efficiencies**

(Source: Mussa 2004)

SS' is an isoquant of a fully efficient firm; it represents various combinations of inputs, which efficiently produce a given level of output. AA' is an isocost line; it represents various amounts of inputs that can be acquired for a given level of expenditure outlay. Point Q' where the isoquant SS' is tangential to the isocost line AA' represents an equilibrium combination of inputs x_1 and x_2. Points Q, R and P represent possible quantities of inputs used to produce a unit of output. If a given firm uses quantities of inputs defined by the point P, to produce a unit of output, the technical inefficiency of that firm could be represented by the distance QP, which is the amount by which all inputs must be proportionally reduced without a reduction in

[1]The assumption of constant returns to scale allows technology to be represented using the unit isoquant, where an isoquant is defined as a curve where a given level of output is produced for various combinations of inputs.

output. This is usually expressed in percentage terms by the ratio QP/OP, which represents the percentage by which all inputs used must be reduced to achieve technically efficient production. The technical efficiency (TE) of a firm is most commonly measured by the ratio:

$$TE_i = OQ/OP = 1 - QP/OP \tag{2.1}$$

Technical efficiency is therefore equal to one minus technical inefficiency. It takes a value between zero and one, and hence provides an indicator of the degree of technical inefficiency of a firm. A value of one indicates the firm is fully technically efficient. For example point Q because it lies on the efficient isoquant.

If the input price ratio, represented by the isocost line AA' is also known, allocative efficiency may be calculated. The allocative efficiency (AE_i) of the firm operating at P is defined to be the following ratio:

$$AE_i = OR/OQ \tag{2.2}$$

since the distance RQ represents the reduction in production costs that would occur if production were to occur at allocatively (and technically) efficient point Q', instead of at the technically efficient, but allocatively inefficient, point Q. the total economic efficiency (EE_i) is defined to be the ratio:

$$EE_i = TE_i * AE_i = (OQ/OP)*(OR/OQ) = (OR/OP) \tag{2.3}$$

The comparative performance analysis that the study conducts focuses on the technical efficiency of improved and traditional fish smoking kilns. Technical efficiency is defined relative to a notion of best practice, which is referred to as the efficiency frontier. Figure 2.2 illustrates how technical efficiency is defined and therefore measured. Consider a production process in which a single input (x) is used to produce a single output (y).

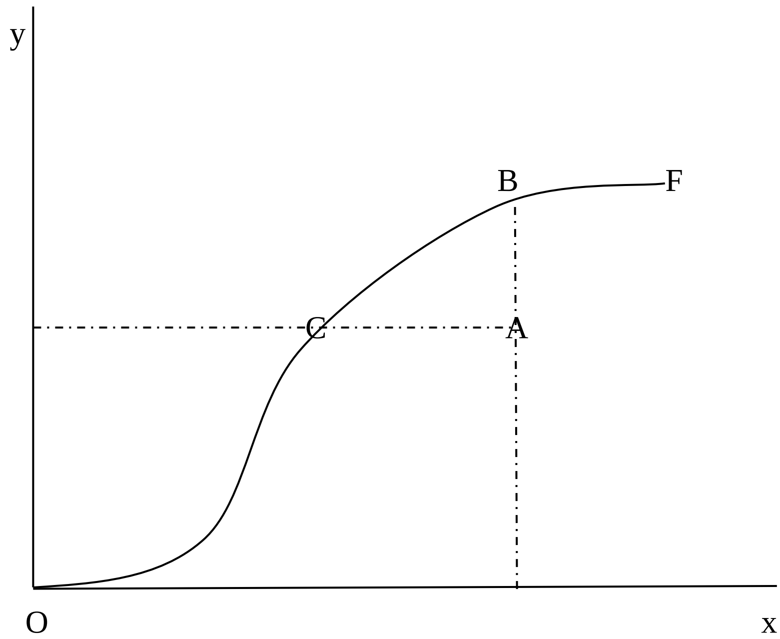

Figure 1.2: Efficiency Frontier and Technical Efficiency

(Source: Mussa 2004)

The line OF represents an efficiency frontier, which can be used to define the relationship between the input and output. The frontier represents the maximum output attainable from each input level. It therefore reflects the current state of technology. A firm can either operate on the frontier if they are technically efficient or beneath the frontier if they are not technically efficient. Point A represents an inefficient point; whereas B and C represent efficient points. Point A is inefficient because a firm operating at this point could increase output to the level associated with point B without requiring more inputs. The further away the farm is from the efficient frontier, the more technically inefficient it is. Hence, measuring the level of inefficiency is equivalent to measuring the distance from the efficiency frontier. All measure of technical efficiency therefore estimate this distance from the frontier.

2.2.2 Measurement of Technical Efficiency

Recent literature on the relative measure of technical efficiency shows that there are two types of estimators that are used. The first approach is data envelopment analysis (DEA) and the second is Stochastic Frontier Analysis (SFA). The main difference between the two branches is that DEA is a non-parametric estimator that assumes a deterministic production function while SFA is a parametric and stochastic estimator. The DEA methodology was introduced by Charnes, Cooper, and Rhodes (1978). It is based on mathematical programmer approach without imposing any assumptions about functional forms and does not take into account random errors and/or good and bad luck. Thus, the efficiency estimates may be biased under the production process, which largely involve stochastic elements. In contrast, the stochastic production frontier approach imposes an explicit functional form and distribution assumption on the data and can account for random errors (such as luck and weather). SFA uses statistical techniques to estimate a production frontier and estimate efficiency relative to this production frontier.

In this study the stochastic frontier production approach to measuring efficiency is chosen over the DEA approach for the following reasons. First, it ably captures the inherent stochasticity prevalent in fish smoking arising mainly from weather disturbances. This stochasticity cannot be captured by the DEA approach.

Second, it makes possible the testing of hypotheses regarding the existence of inefficiency and also regarding the structure of production technology, which cannot be done in a DEA framework. Finally, SFA ably handles measurement errors, which cannot be captured by the DEA approach.

2.2.3 Estimation of the Stochastic Production Function

Meeusen and Broeck (1977), and Aigner, Lovell and Schmidt (1977), independently proposed the estimation of the stochastic frontier production function. The specification permits output to be specified as a function of some controllable factors of production, random noise and a technical inefficiency term. Upon choosing a functional form for the production function, these authors propose the following model:

$$y_i = f(x_i;\beta)\exp(v_i - \mu_i) \tag{2.4}$$

where y_i is the vector of observations on output (e.g. weight of smoked fish per initial weight of fish) of the ith kiln; x_i is a vector of inputs it uses to smoke a given weight of fish; and β is a vector of estimated parameters. The term v_i is a random variable that accounts for random effects (beyond the control of the firm), which is assumed to be normally distributed with a constant variance [i.e. $v_i \sim N(0,\sigma_v^2)$] and is independent of μ_i. It represents random variations in the economic environment facing production units, reflecting luck, weather, measurement errors, and omitted variables from the model (Aigner et al., 1977).

μ_i is a non-negative random variable that is assumed to account for pure technical inefficiency in production and it is called a technical inefficiency effect. It represents a variety of features that reflect inefficiency such as kiln-specific knowledge, skill and experience of the smoker, and other disruptions to production. Following Coelli (1995), it is assumed to be independently (but not identically) distributed as truncation (at zero) of the normal distribution with mean, μ_i, and variance, σ_μ^2 such that it is distributed as $N(\mu_i \delta_i^2)$ [2],

$$\mu_i = z_i \delta + \omega_i \tag{2.5}$$

where z_i is the vector of explanatory variables associated with the technical inefficiency of production of the ith firm, δ is unknown vector of coefficients that is to be estimated, and ω_i is a (iid) random term, which is defined by the truncation of the normal distribution with zero mean and variance, σ_μ^2, such that the point of truncation is $-z_i\delta$ i.e. $\omega_i \geq z_i\delta$. These assumptions are consistent with μ_i being a non-negative truncation of the $N(z_i\delta, \sigma_\mu^2)$ distribution.

It should be noted that both the frontier model, Equation 2.4 and the inefficiency model, Equation 2.5 may include intercept parameters if the inefficiency effects are stochastic and have distributional properties (Coelli, Rao and Battese,

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[2] The technical inefficiency effect μ_I can be assumed to follow different distributions for example it can be half-normal N (0, σ^2_u) (Aigner *et al.*1977). It can also follow a gamma distribution (Greene 1982), a truncated normal at zero (Battese and Coelli. 1992) and an exponential distribution (Meeusen and Broeck, 1977). However, a study by Parikh *et al.* (1995) showed that there is a negligible difference in the average of inefficiency specified in a half-normal, exponential and truncated normal distribution.

1998). Moreover, stochastic frontier requires a priori functional form specification. This means that it is necessary to impose restrictions on the model. By doing that, these restrictions could be tested by using the generalised likelihood ratio (LR) which is computed as:

$$LR = -2[\ln L(H_0) - \ln L(H_1)] \tag{2.6}$$

where $L(H_0)$ and $L(H_1)$ represents the values of the log-likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. The restrictions form the basis of the null hypothesis, while the unrestricted model being the alternative hypothesis. The generalised Log-likelihood ratio has a chi-squared χ^2 distribution with the degrees of freedom equal to the difference between parameters involved in the null and the alternative hypothesis (Coelli et al., 1998).

In order to test the specification of the models, a number of tests have been proposed with the standard being the one-sided generalised likelihood ratio-test for the existence of a frontier (presence of technical inefficiency) (i.e. $H_0 : \gamma = 0$). This test has an asymptotic distribution ($0 < \gamma < 1$) and the critical values of the test are obtained from Kodde and Palm (1986). In case of failing to reject the null hypothesis (i.e. no inefficiency), then there is no evidence of technical inefficiency in the data and the production frontier is identical to a standard production frontier. The other key test is the correct functional form of the stochastic production function. The translog form is tested against the Cobb-Douglas form. Given Equation 2.6, $L(H_0)$ is the value of the log-likelihood function under the null hypothesis that the coefficients of the second order and the interaction terms in the translog function are equal to zero (i.e. $H_0 : \beta_{jk} = 0$). The null is therefore that the correct functional form is Cobb-Douglas. $L(H_1)$ is the value of the log-likelihood function under the alternative hypothesis that the coefficients of the second order and the interaction terms in the translog function are not equal to zero. (i.e. $H_0 : \beta_{jk} \neq 0$). The alternative hypothesis is therefore that the correct functional form is the transcendental logarithmic.

Based on the model estimations, the output for each firm will be compared with the frontier level of output that is known as the best output given the level of inputs employed, and this deviation indicates the level of inefficiency of the firm. Therefore, the technical efficiency score for the i[th] firm in the sample (TE_i) under given equations (2.4) and (2.5) that would be defined as the ratio of observed output to the corresponding best output is given by (Coelli et al., 1998):

$$TE_i = \frac{y_i}{\exp(\beta \mathrm{I} nx + v_i)} = \frac{\exp(\beta \mathrm{I} nx + v_i - \mu_i)}{\exp(\beta \mathrm{I} nx + v_i)} = \exp(-\mu_i) = \exp(-z_i\delta - w_i) \quad (2.7)$$

where TE_i is relative technical efficiency of the firm (0<TE<1). Note that, when μ_i=0 then the firm lies on the stochastic frontier and known as technically efficiency. If μ_i>0, the i[th] firm lies below the frontier, which means that the firm is inefficient.

While the individual inefficiency effects ($\mu_i s$) are not directly observable, the individual technical efficiencies (TE_i) are predicted using the best predictor that is based on the expectation of $\exp(\mu_i)$ conditional on ($v_i - \mu_i$). Battese and Coelli (1988) derive the best predictor of the technical efficiency of firm i, $TE_i = \exp(-\mu_i)$ as:

$$E[\exp(-U_i) \ |(V_i - U_i)] = \left[\frac{1-F\{\sigma_A + \gamma(V_i - U_i)/\sigma_A\}}{1-F\{\gamma(V_i - U_i)/\sigma_A\}}\right]\exp\{\gamma(V_i - U_i) + \sigma^2{}_A / 2\} \qquad (2.8)$$

where $\sigma_A^2 = \gamma(1-\gamma)\sigma^2$ and the variance parameters (σ_υ^2 and σ_μ^2) are expressed as follows:

$$\sigma^2 = \sigma_\nu^2 + \sigma_\mu^2 \qquad (2.9)$$

and

$$\gamma = \frac{\sigma_\mu^2}{\sigma^2} \qquad (2.10)$$

γ is a variance-ratio parameter, and is important in determining the 'superiority' of the stochastic production frontier over the traditional average production function. γ takes values ranging from 0 to 1. The average production function has a gamma value of zero, meaning that there is no technical inefficiency, or in other words, firms are operating at full capacity. A gamma value of one implies a full-frontier model, where the random variables ν_i are not present in the model. In order to check whether a stochastic frontier production function is necessary, direct reference can be made to the value of gamma and then determine whether it is significantly different from zero (Coelli et al., 1998).

Assuming that the technical inefficiency effect μ_i follows a truncated normal as prior indicated, the mean technical efficiency is measured by:

$$E[\exp(-\mu_i)] = 2[\exp(-\gamma\sigma^2 / 2)][1 - F(\sigma\sqrt{\gamma})] \tag{2.11}$$

The mean technical efficiency measures the percentage of potential output that firms are on average actually producing. For example, a mean technical efficiency of 80% indicates that firms are on average producing 80% of their potential output. This means that they can increase their output by 20% to attain the maximum possible level of output.

The stochastic frontier production function given in Equation 2.4 can be estimated by corrected ordinary least squares (COLS) which has an adjusted intercept to ensure that it becomes unbiased since using OLS the intercept coefficient is biased or by the maximum likelihood estimation method (MLE). This study uses MLE because it is asymptotically more efficient than the COLS estimator (Coelli et al., 1998).

2.3 Empirical Literature

Over the years, there have been a considerable number of studies on estimating stochastic production frontiers and technical efficiencies of natural resource vessels. Pitt and Lee (1981) and Kalirajan (1981) adopted a two-stage approach for the explanation of the inefficiency effects in cases of the Indonesian weaving industry and paddy production, respectively. The first stage of this approach is that both the stochastic frontier production function and the predicted technical inefficiency effects are specified and estimated, given the assumption that these inefficiency effects are identically distributed, while the second stage specifies a regression model for the prediction of the technical inefficiency effects, but with a contradiction in the assumption of identically distributed inefficiency effects in the stochastic frontier.

Chirwa and Mwafongo (1998) estimate three stochastic production and technical efficiency models of farmers in Southern Malawi assuming that the technical inefficiency effects follow half-normal, truncated normal and exponential distributions. The results show that on average farmers are inefficient in Malawi and could increase output by using the same input levels by 47 percent, 48 percent and 32 percent assuming half-normal, truncated normal and exponential distributions of the one-sided error term, respectively. They also find that those farmers that partly use hired labour and those that apply fertilizer are more technically efficient compared with those that only use family labour and do not use fertilizers. The study also shows that small farms are more efficient compared with larger farms.

Mussa (2004) used stochastic production frontier analysis to investigate the technical efficiency of two samples of smallholder farmers in southern Malawi; one involving farmers adopting integrated aquaculture-agriculture (IAA) technology and the other involving non-adopters. The study revealed that technical efficiency is low in non-IAA farmers with a mean of 49% explained primarily by sex of the principal farmer. IAA farmers on the other hand achieve a mean efficiency level of 63%.

Kareem, Dipeolu, Aromolan and Williams (2007) in Ogun State in Nigeria applied the stochastic frontiers production analysis to estimate the technical, allocative and economic efficiency among the fish farmers in the state. The results of economic efficiency revealed that fish farming is economically efficient with a range of between 55% and 84% efficiency level suggesting a favourable hope for the agro-allied industry such as poultry and cottage industries in the state. The result of hypothesis of inefficiency sources models showed that, years of experience of fish farmers was significant at 1% probability level indicating the factor contributing to the fish farming experience in the state. Thus, the efficiency was due to the fact that farmers were experienced and fairly educated.

Lien, Stordal and Baardsen (2007) applied a stochastic production frontier analysis to evaluate forest management efficiency impacts of important factors in Norway. The factors included property and owner characteristics, outfield-related and agricultural activities, off-property income and geographical location in central or remote areas. It was found that many forest owners were technically inefficient, and there existed opportunities for improved performance. Off-property income was found to have an estimated negative impact on technical efficiency, the inefficiency arising (weakly) with increasing share of household incomes from outfield activities, and properties in urban centred areas were less efficient than those in remote areas.

Ajang, Ndome and Ingwe (2010) studied fish processing parameters with regards to organoleptic evaluation and cost benefit analysis using the chorkor and traditional fish smoking altar in Nigeria. The chorkor smoked fish had an attractive colour, good taste and was of good quality. The Cost benefit analysis showed that at all levels of the operation, the chorkor was superior to the traditional smoking altar in terms of all indices of profitability. A major benefit of chorkor fish processing technology was that it required much lower fuel wood.

2.4 Conclusion of the Literature Review

In this chapter an attempt was made to review literature on deforestation in Malawi. Theoretical literature reviewed in this chapter showed that there are two main ways of estimating technical efficiency, namely parametric and non-parametric mathematical programming approach. Considering the various advantages that the parametric approach has over non-parametric, technical efficiency will be estimated using parametric approach in the present study. The chapter also discussed on technical efficient empirical studies that have been conducted in the fisheries, agriculture and forestry sectors over the years.

This study benefits from the theoretical and empirical literature, which has been presented in the chapter to specify the econometric models in the following chapter.

CHAPTER 3

METHODOLOGY

3.0 Introduction

In this chapter we focus on five areas. Section 3.1 provides a brief description of the study area. In Section 3.2, we present the sources of data, collection tools and sampling techniques employed in the study. The specific form of the econometric model used in the study including their expected signs is provided in Section 3.3. A discussion is made in Section 3.4 with respect to diagnostic tests that are conducted to ensure that the empirical results are reliable. Finally, Section 3.5 provides the econometric package used to analyse data.

3.1 Study Area

The study was conducted in the Southern Region of Malawi. Specifically, the study was carried out in the three Lake Chilwa basin districts of Phalombe, Zomba and Machinga. Approximately 60% of the basin population depends on farming for their livelihoods together with petty trading and fishing. In Malawi, 55% of the smallholder farmers have less than one hectare of cultivatable land (Government of Malawi, 2002). However, approximately 75% of the farming population in the study area has less than one hectare on which to cultivate; thus fishing and petty trading form a significant source of livelihood for most families in the basin. Lake Chilwa contributed on average 24% of the total annual fish production in Malawi in the 1970s (Furse, Morgan and Kalk, 1979). This reduced to 20% in the 1990s and data from 2000-2009 indicates that Lake Chilwa now contributes 10.54% of the country's fishery (Government of Malawi, 2010). The mean total landings for Lake Chilwa for the same period are at 7,537.093 metric tonnes per year lower than the peak of 12,000 tonnes per year in the '90s (Government of Malawi, 1998).

The Lake Chilwa Basin has been classified into hot spots which have been identified according to socio-economic and environmental criteria. The study follows the same approach by identifying one hotspot in each of the three districts to which the basin stretches. At least two fish processing sites per hotspot were selected based on their relative importance in fish smoking. The study sites comprised Swang'oma beach and Njalo Island in TA Chiwalo in Phalombe district; Kachulu beach, Mchenga beach and Chisi Island in TA Mkumbila in Zomba district; and Gulf and Fresh fishing villages in TA Mposa in Machinga district.

3.2 Data Collection and Sample Design

The study mainly collected quantitative data to achieve its objectives. Two research tools were used, namely: field experiments and semi-structured questionnaires. Since economists are never sure of how well observed data was generated because of the non-experimental nature of the field (Davidson, 2000), experiments used in this study were expected to close this gap. The experiments were conducted at Swang'oma in Phalombe District. In order to estimate the level of technical efficiency of the traditional fish smoking methods and that of improved kilns, two blocks of experiments were concurrently set up: one for smoking fish on traditional method and the other on improved kiln. Approximately equal amounts of fish of the same species and sizes were smoked on each kiln type using the same type of firewood. The splitting of the fish into the equal proportions for smoking was done after initial sun-air drying. All fish smoking was done by the same person; this was done in order to hold factors like smoker's experience, education and age constant. The smoker was equally competent in using both methods of smoking fish. Kiln specific data on volume of firewood used (m^3), labour hours (hrs), total processing time (hrs) were collected as input variables to estimate the level of inputs. On the other hand, weight of smoked fish (kg) from each kiln type was captured as an output variable. In the quest of increasing data reliability, the experiments were replicated 33 times.

Semi-structured questionnaires were administered to fish smokers and kiln owners to complement on the data collected through field experiments. The semi-structured questionnaire collected socio-economic information of the fish processors, their fish processing experience, quantities of fish processed, amount of labour involved in fish smoking, value addition accrued to processing, species and quantities of firewood used. Additionally, data was collected from kiln owners on the numbers of kilns owned, their processing experience, cost of constructing and maintaining the kilns, revenue obtained from renting the kilns and their level of influence on fish smokers.

A census of kilns was taken during preliminary visits to the study sites in June 2011 and the generated kiln register was used as a sampling frame for the study. The study area was classified into four strata based on their geographical characteristics. The strata included Swang'oma and Njalo Island in Phalombe, Mchenga and Kachulu in Zomba, Namakwaila and Mkoka beaches in the Chisi Island in Zomba, Gulf and Fresh fishing areas in TA Mposa in Machinga. Random samples were drawn proportional to the total number of kilns in each stratum using the following sample size determination formula.

$$n = \frac{NZ_{\alpha/2}^2}{4Nd^2 + Z_{\alpha/2}^2} \qquad (3.1)$$

where n is the sample size in each stratum; N is the total number of kiln owners in the stratum; and d is the precision level.

The study therefore used stratified random sampling as its sampling technique and this sampling procedure generated 130 respondents (65 fish smokers and 65 kiln owners). The data was collected between July and August 2011.

3.3 Model Specification

This section specifies the empirical model in recognition of the fact that the choice of the functional form in an empirical study is of primary importance, since the functional form can affect the results (Kebede, 2001).

Production functions used in cases of the individual vessel level or total fishery level for estimating the relative contribution of the factors of production, include Cobb-Douglas (CD) production functions (Hannesson, 1983), Constant Elasticity of Substitution (CES) production function (Campbell and Lindner, 1990) and the transcendental logarithmic (translog) production functions (Squires, 1987). However, literature on economic studies in the fisheries sector has shown that the CD and translog are the most commonly used functions. The translog function reduces to the CD function if all the coefficients associated with the second-order and interaction terms of inputs are zero.[3] Guilkey, Lovell and Sickles (1983) compared the two commonly used functional forms for production frontier: the translog and the Cobb-Douglas. They concluded that the translog form provides a relatively dependable approximation to reality. The translog form is also more flexible in permitting substitution effects among inputs than CD function. In this study, a translog stochastic frontier model is therefore estimated first, and is then tested against CD functional form. The generalised log-likelihood test is conducted to determine the appropriateness of the function. The translog model is estimated for both traditional and improved fish smoking kilns and is specified as follows:

$$\begin{aligned}\ln(\text{WSFper}) = {} & \beta_0 + \beta_1 \ln FWDper + \beta_2 \ln LBRper + \tfrac{1}{2}\beta_3(\ln FWDper)^2 + \tfrac{1}{2}\beta_4(\ln LBRper)^2 \\ & + \beta_5(\ln FWDper.\ln LBRper) + v_i - \mu_i\end{aligned} \tag{3.2}$$

where *ln* represents the natural logarithm which is employed in order to linearise the translog function.

WSFper is the observed output value of the fish smoking kiln representing weight of smoked fish per initial fish weight. WSFper value is unitless and in this model, the smaller output value is most preferred as it implies less residual moisture in the smoked fish; consequently, longer shelf-life.

FWDper represents the volume of firewood used per initial fish weight in each type of kiln. The unit measure for firewood volume per initial fish weight is cubic metres per Kg (m^3/Kg). The hypothesis is that volume of firewood per initial fish weight negatively relates to the weight of smoked fish per initial fish weight.

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[3]The number of interaction terms is given by the formula g=m (m-1)/2, where g is the number of interaction terms and m is the number of factors of production.

LBRper is the total labour per initial fish weight smoked (expressed in labour hours per Kg). Labour input for each kiln type is calculated by taking the summation of time taken for each sub activity in the fish smoking process from initial sun air drying until the fish is smoked to desired moisture level. The sub activities include spreading fresh fish on drying racks for initial sun air drying, arranging on wire meshes, lighting up the fire, rotating fish on the racks and reinserting firewood pieces into combustion chamber to ensure that fire is maintained. Labour per initial fish weight is expected to negatively impact output (weight of smoked fish per initial weight).

$\beta_0 - \beta_5$ are the parameters to be estimated. The term v_i is the statistical noise that accounts for random effects that cannot be controlled by the decision making unit, such as measurement errors, omitted variables and weather conditions. v_i is assumed to be normally distributed with constant variance. On the other hand, μ_i is the technical inefficiency effect that is a non-negative random variable and accounts for pure technical inefficiency in production. Technical inefficiency on the other hand, accounts for those factors that can be controlled by the decision making unit and is assumed to be independently and identically distributed with truncations (at zero) of the normal distribution.

It should be noted that the translog specification provided in Equation 3.2 first considers the relationship of each input (FWDper and LBRper) with the output. Second, the model examines the relationship of the square of each input (interaction of each input with itself) i.e. $(\text{FWDper})^2$ and $(\text{LBRper})^2$ with the output and finally it considers the relationship between the interaction between the two inputs i.e. (FWDper) (LBRper) with the output.

Of particular mention is the inclusion of a constant term, ½ as part of the coefficient associated with the second-order terms of inputs in the specification of the translog model specification provided in Equation 3.2; it should be noted that not all authors include this constant term. Fan (1999) and Rivera, Costantin and Martin (2008) are some of such authors who have included the constant term in their model specification. The constant term is included only for mathematical computation. When differencing, it cancels out with the power 2 on the quadratic function.

Technical inefficiency (μ_i) is assumed to be a function of a set of explanatory variables; δ is an unknown vector of coefficients to be estimated and ω_i is random error term (Battese and Coelli, 1992). Thus, the technical inefficiency model is defined by:

$$\mu_i = z_i\delta + \omega_i \tag{3.3}$$

Explanatory variables for technical efficiency could include age, education and experience of the smoker. Factors like wood type and size of fish could also have been investigated as determinants of technical efficiency. It should however be noted that determinants of technical inefficiency were not a focus of this study; as such, they were all held constant. For instance, factors like smoker's age, education and experience were contained by using the same smoker for all the experiment replications. Similarly, fish size and firewood type were fixed by using same fish sizes (species) and firewood types for each experimental replication set.

3.4 Diagnostic Tests for the Econometric Model

This section describes the diagnostic tests that are conducted at the econometric analysis levels of data for stochastic frontier analysis. The reliability of our empirical results depends on whether or not the models that are being estimated satisfy certain criteria. Specifically, our models have to be correctly specified, and the assumptions or restrictions made must be holding. Incorrect functional specifications and violations of assumptions can lead to incorrect conclusions and recommendation (Gujarati and Porter, 2009). This study uses the generalised log-likelihood ratio test to examine a number of hypotheses. First, the generalised log-likelihood ratio test has been used to test for the pooling assumption. Second, it has been used to determine the appropriate empirical functional form for the production function in fish smoking. Third, it has been used to ascertain the presence of the technical inefficiency effects in the specified production function. Finally, the test is used to examine whether the probability distribution of the technical inefficiency effects follow truncated normal or half normal.

3.4.1 Testing the Pooling Assumption

Log-likelihood test is used to test the pooling assumption. We first estimate a pooled regression regardless of the fish smoking kiln type. Then individual kiln type regressions are also estimated to compare the pooled regression with the individual separate kiln models. The null hypothesis is that the coefficients of the pooled regression will be the same as those of separate kiln type models. If the null hypothesis is true, then there would be no need of running separate regressions. However, if we reject the null hypothesis, then separate regressions would have to be estimated. It implies that pooled estimates are concealing valuable information of each of the kiln models.

3.4.2 The Correct Empirical Functional Form

The translog functional form is tested against the Cobb-Douglas (CD) functional form to establish which functional form adequately captures the production behaviour of fish smoking kilns. Given Equation 2.6, L (H_0) is the value of the log-likelihood function under the null hypothesis that the coefficients of the second order and the interaction terms in the translog function defined by Equation 3.2 are equal to zero. The null is therefore that the correct functional form is Cobb-Douglas. L (H_1) is the value of the log-likelihood function under the alternative hypothesis that the coefficients of the second order and the interaction terms in the translog function defined by Equation 3.2 are not equal to zero. The alternative hypothesis is therefore that the correct functional form is the transcendental logarithmic.

3.4.3 Presence of Technical Inefficiency Effects

Having established the correct functional form, the generalised log-likelihood ratio statistic is then used to establish whether or not technical inefficiency effects are present in the specified functional model. In this case, L (H_0) is the value of the log-likelihood function under the null hypothesis that there are no technical inefficiency effects for both models. L (H_1) is the value of the log-likelihood function under the alternative hypothesis that technical inefficiency effects are valid for both models. If the inefficiency effects are absent from the model, as specified by the null hypothesis, then the statistic is approximately distributed according to a mixed Chi-square distribution. In this case, critical values for the generalised likelihood-ratio tests are obtained from Table 1 in Kodde and Palm (1986). If this null hypothesis is true, the stochastic frontier model reduces to ordinary least squares regression model with normal errors.

3.4.4 The Distribution of the Technical Inefficiency Effects

After establishing that the technical inefficiency effects are valid in their correct functional form, the next step is to determine their probability distribution. Battese and Coelli (1992) posited that the technical inefficiency effects followed a truncated normal distribution where truncation is at zero. The truncated normal is the generalisation of the half-normal distribution. The assumption allows us to look at the determinants of technical inefficiency, which cannot be done if the technical inefficiency effects are half-normal. The generalised log-likelihood ratio test is used to investigate whether the technical inefficiency effects follow a truncated normal distribution or half-normal distribution. In this case, L (H_0) is the value of the log likelihood function under the null hypothesis that the technical inefficiency effects are half normal for both models. L (H_1) is the value of the log likelihood function under the alternative hypothesis that the technical inefficiency effects follow a truncated normal distribution for both models.

3.5 Estimation of the Avoided Deforestation

The study also aims at estimating the extent of deforestation that would be avoided by using energy-saving kilns (possibly technically efficient as well). The average volume of firewood saved by using the energy-saving kiln is calculated as follows:

$$\mathrm{V_S} = V_1 - V_2 \tag{3.4}$$

where V_s is the average volume of firewood saved (m^3) by using the more efficient fish smoking kiln; V_1 and V_2 represent average volumes of firewood used in the each kiln type (m^3) to smoke a given amount of fresh fish but V_1 - V_2 should be different from zero.

The volume of firewood that would be saved by using the energy saving kiln is then multiplied by the total number of fish smokers taken during a pre-visit to the study area and average quantity of fresh fish smoked per fish smoker in a day (calculated from the survey data) to obtain the minimum volume of firewood saved in a day. This calculation assumes that each fish smoker smokes fish once a day.

Using Kambewa, Mataya, Sichinga and Johnson (2007) estimate that 1.4 million cubic metres of wood is equivalent to clearing 15,000ha of forestland, we then convert the volume of wood saved into forestland avoided from being cleared. This estimate is then used to infer to the forestland being saved in a specified period.

3.6 Data Analysis

The econometric software package, STATA 11.2 is used for data analysis. STATA 11.2 is firstly used to conduct descriptive analysis. Secondly, the software is used to estimate the translog stochastic frontier. Finally, the same package has been used to perform diagnostic tests for the econometric model.

3.7 Conclusion of the Methodology

It has been shown in the chapter that there are several functional forms that can be used to estimate the relationship between inputs and output. The translog and Cobb-Douglas were however found to be the most commonly used functional forms. The translog functional form has been chosen because it permits a larger flexibility than Cobb-Douglas functional form. It has however been argued that, our a priori choice of the translog function needs to be tested against the CD form to determine the appropriate functional form. In addition, several tests that are conducted to establish the reliability of the empirical results have also been discussed.

CHAPTER 4

EMPIRICAL RESULTS AND INTEPRETATION

4.0 Introduction

This chapter presents and interprets the results of the descriptive and econometric analyses. It also provides results and interpretation of the diagnostic tests and the frequency distribution of technical scores for both traditional and improved kiln models. In addition, the chapter provides an insight into avoided deforestation estimations as a result of using the more efficient kiln. Specifically, Section 4.1 presents the descriptive analysis of the fish processors in the study area. Section 4.2 presents descriptive statistics of variables used in stochastic frontier analysis. We present and discuss the results of the diagnostic tests for traditional and improved kilns in Section 4.4. In Section 4.5 of this chapter, frequency distributions of technical efficiency scores for both kilns are discussed and we finally discuss the avoided deforestation in Section 4.6.

4.1 Descriptive Analysis of the Fish Processors

Out of the 65 fish smokers interviewed, 57 were male; representing 88.7% of the sample. This is an indication that fish smoking is a male dominated activity. The male dominance in fish smoking was attributed to the nature of the work involved (from sourcing the fresh fish to the point the fish is smoked) which tend to favour males.

The study showed that the majority of the processors did not have high levels of education, with about 70% of them having attained only primary school as their highest level of education. Up to 14% of the sample indicated to have not attended any formal education which means only 16% of processors had education attainment above primary school. This shows that the levels of education attainment among fish smokers are very low, which is worrying because low education levels limit people's ability to transact with the society. On the other hand, the low education levels among fish smokers show that education is not a barrier to entry into fish smoking activities. It may also imply the availability of cash despite lower levels of education attainment.

The study found that the smokers operating in the Lake Chilwa basin are mostly migrant smokers. Approximately 86% of the smokers interviewed were migrant smokers while only 14% were resident fish smokers. Migrant fish smokers mostly come from different parts of the districts that make up Lake Chilwa Basin but that do not boarder the Lake. Very few respondents reported to come from places outside the lake Chilwa Basin. The results show that 63% of the smokers rely on fish smoking as their primary livelihood activity while 30% of smokers are also farmers. Such smokers temporarily switch from fish smoking business to concentrate on farming between December 1 and end February. Coincidentally, the lake is also closed during the same period. Fish catch levels are relatively lower during this period. However, some smokers still continue smoking fish during the closed season. They smoke fish caught in fishing basket traps (*Mono*).

The results also showed that about 89% of the smokers in the sample were married with only 6% of the respondents being single and the remaining 5% being either divorced or widowed. This implies that fish smoking activity contributes to supporting households' needs.

Table 4.1 presents the description of the fish smokers who were interviewed during the study.

Table 4.1: Description of Sampled Fish Smokers

Characteristics	Frequency	Percentage (%)
Education		
None	9	13.8
Standard 1 to 4	21	32.3
Standard 5 to 8	24	36.9
Secondary and other	11	16.9
Marital Status		
Married	58	89.2
Widowed	2	3.1
Divorced/Separated	1	1.5
Never married	4	6.2
Main Occupation		
Farmer	9	13.8
Fisher	5	7.7
Fish Trader	4	6.2
Fish Smoking	41	63.0
Business/Petty Trade	4	6.2
Piece works	1	1.5
Student	1	1.5

4.2 Stochastic Frontier Analysis

Table 4.2 presents descriptive statistics for the variables used in the stochastic frontier analysis. The empirical results showed that mean kiln output (measured as a proportion of the initial fish weight retained as weight of smoked fish) for the traditional kilns was 0.418; implying weight loss of about 58% attributed to moisture removed from the fish through traditional smoking. On the other hand, the mean kiln output for the improved kiln was 0.476; implying about 52% weight loss (moisture loss) through smoking using improved kilns. It should be pointed out that the difference between the two output means is statistically significant at 5% ($p = 0.0226$). This is an indication that traditional fish smoking removes more moisture from the fish than the improved kilns. It should however be emphasised that the residual moisture content for smoked fish from both types of kilns is within the acceptable moisture content level of between 12-14%. In addition, fish smokers who were interviewed conceded that fish smoked on improved kiln has superior sensory characteristics as opposed to smoked fish from traditional kilns. These sensory characteristics include even-browning of the fish, better taste, and lower levels of rancidity. These attributes are crucial in ensuring that smoked fish fetches higher prices at the market.

Table 4.2 also shows that on average $0.015m^3$ of firewood was used to smoke one kilogram of fish on traditional kiln and that $0.007m^3$ of firewood was used to smoke one kilogram of fish on improved kiln. The mean difference in the amount of firewood used between the two types of kiln is not statistically significant at 5% ($p = 0.1385$). Consequently, there is no evidence of firewood usage differentials between the two methods of smoking fish.

The results also show that 0.271 and 0.194 labour hours were used to smoke one kilogram of fish on traditional and improved kilns respectively. The mean difference between the improved and traditional kilns in labour per initial fish weight is however statistically significant at 5% ($p = 0.0117$). Empirically, the results have showed that fish smoking using traditional kilns demands more labour than using improved kilns.

Table 4.2: Summary Statistics of Variables of Stochastic Frontier Production

Variable		Unit of Measure	Traditional Smoking				Improved Kilns			
			Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Output	**WSFper[4] (Y)**		0.418	0.110	0.273	0.75	0.476	0.124	0.325	0.956
Input	**FWDper[5] (X_1)**	**m^3/Kg**	0.015	0.031	0.002	0.181	0.007	0.009	0.001	0.050
	LBRper[6] (X_2)	**hrs/Kg**	0.271	0.148	0.102	0.833	0.194	0.087	0.075	0.554

4.3 Results of Diagnostic Tests

This section focuses on the results of the diagnostic tests that were applied on the economic model using the log-likelihood test. We first test for pooling to ascertain the need to estimate separate models for the two types of smoking kilns. Second, we use log likelihood test to establish the correct empirical stochastic production functional form which is adequately represented by the data. Using the same test, we also seek to establish the presence of technical inefficiency effects before determining their distribution.

4.3.1 Results of the Pooling Test

The test for pooling showed that the null hypothesis that coefficients of the pooled regression were the same as those of separate kiln models was rejected at 5%

[4] WSFper = Weight of smoked fish per initial fish weight

[5] FWDper = Volume of firewood per initial fish weight

[6] LBRper = Labour per initial fish weight

(p = 0.025). Results of the pooling test are presented in Table 4.3. Following the rejection of the null, separate regressions were estimated and results are presented in the subsequent tables.

Table 4.3: Results of Pooled Test

Null Hypothesis	Log-likelihood under the H_0	P-Value	Decision (5 % level)
Coefficients of the pooled regression are the same as those of separate regression	17.50	0.025	Reject

4.3.2 Diagnostics for Traditional Fish Smoking Kiln

The test results presented in Table 4.4 ascertains the validity of the assumptions made and the correct functional form for traditional fish smoking. The null that Cobb-Douglas is the correct functional form was rejected at 5% significance level (p = 0.0127). This implies that translog functional form adequately captures the production behaviour in traditional smoking. The null hypothesis of no technical inefficiency effects in the traditional fish smoking kiln model was not rejected at 5% (p = 1.0000); implying that there was no evidence of technical inefficiency in the data. Consequently, the production frontier is identical to standard production function with normal errors. This was further confirmed by the small size of the estimated gamma (γ) of the frontier model which was 0.0162 (see Appendix 2); indicating that only 1.62% of the total composite error variance in traditional fish smoking can be explained by variance in technical inefficiency. Since technical inefficiency effects are invalid, we do not examine their distribution pattern.

Table 1.4: Log likelihood Test for Traditional Fish Smoking Kilns

Null Hypothesis	Log likelihood under H_0	P-Value	Decision (5% level)
Frontier is Cobb-Douglas	10.82	0.0127	Reject
No Technical Inefficiency	0.00	1.000	Fail to reject

4.3.3 Diagnostics for the Improved Fish Smoking Kiln

The null that Cobb-Douglas is the correct functional form was not rejected at 5% significance level (p = 0.2422). There was no adequate evidence to reject the null hypothesis; implying that the correct functional form for improved fish smoking kilns is Cobb-Douglas. The null hypothesis of no technical inefficiency effects was not rejected at 5% (p = 1.0000). There was no evidence of technical efficiency in the data and the production frontier is identical to standard production function with normal errors. This was further confirmed by the size of the estimated gamma (γ) of the frontier model which was 0.009; implying that only 0.9% of the total error composite error variance in traditional fish smoking can be explained by variance in technical inefficiency. Since technical inefficiency effects are invalid, we do not examine their distribution pattern.

Table 4.5: Log likelihood Test for Improved Fish Smoking Kilns

Null Hypothesis	Log likelihood under H_0	P-Value	Decision (5% level)
Frontier is Cobb-Douglas	4.18	0.2422	Fail to reject
No Technical Inefficiency	0.00	1.000	Fail to reject

4.3.4 Conclusion of the Diagnostic Tests

In the preceding, we have attempted to establish which stochastic frontier production function best fits the data for traditional and improved fish smoking kilns. The results showed that translog functional form was the correct specification for traditional fish smoking kilns; whereas Cobb-Douglas was the best-fit functional form for improved fish smoking kilns. The diagnostic tests also revealed that technical inefficiencies were invalid in both models. As such the two stochastic production functions were reduced to Ordinary Least Squares models with normal errors.

4.4 Empirical Results of Econometric Models for Traditional and Improved Kilns

This section presents results for the stochastic frontier production function for both traditional and improved kilns. Before estimating separate models for the kilns, an attempt was made to estimate a pooled stochastic model for the kilns. The results of the pooled stochastic model showed that the coefficients elasticity of output (weight of smoked fish per kg of fresh fish) with respect to the individual factors of production (volume of firewood needed to smoke one Kg of fresh fish and labour hours required for the same Kg of fresh fish as inputs) did not have the expected *a priori* negative sign. The results showed that, holding all other factors constant, an increase in a particular factor leads to an increase in output. Pooled regression results showed that the elasticity of output with respect to labour hours per Kg was significant at 5% ($p = 0.017$). The results also show that the elasticity of output with respect to volume of firewood per kg of fresh fish was not statistically significant at 5% ($p = 0.852$).

It should also be pointed out that using log likelihood test, the Cobb-Douglass was found to be the correct empirical form for the pooled regression and that the data showed no evidence of technical inefficiencies.

Following results of the pooling test, separate frontier regressions had to be estimated. The results of the frontier models showed that only coefficients of volume of firewood needed to smoke one Kg of fresh fish in the traditional fish smoking kiln model had the expected *a priori* negative sign though not significant at 5% ($p = 0.943$). It should be noted that only coefficients of labour per kg of fresh fish were significant for both models.

4.5 Mean Technical Efficiency

Figure 4.1 provides the frequency distributions of technical efficiency scores for both traditional fish smoking kilns and improved fish smoking kilns. The figure shows that the estimated technical efficiencies for both kilns are less than one. It is also clear that values of technical efficiencies for both traditional and improved kilns were not very different from each other. The predicted technical efficiencies for improved kilns ranged between 99.436% and 99.452%; whereas those of traditional kilns were between 99.436% and 99.46%. This implies that the potential increase in output arising from the use of improved kilns is almost negligible. Empirical results show that there are no large productivity gains achieved by using improved kilns. Thus the null that there is no difference in mean technical efficiency levels between traditional and improved kilns could not be rejected.

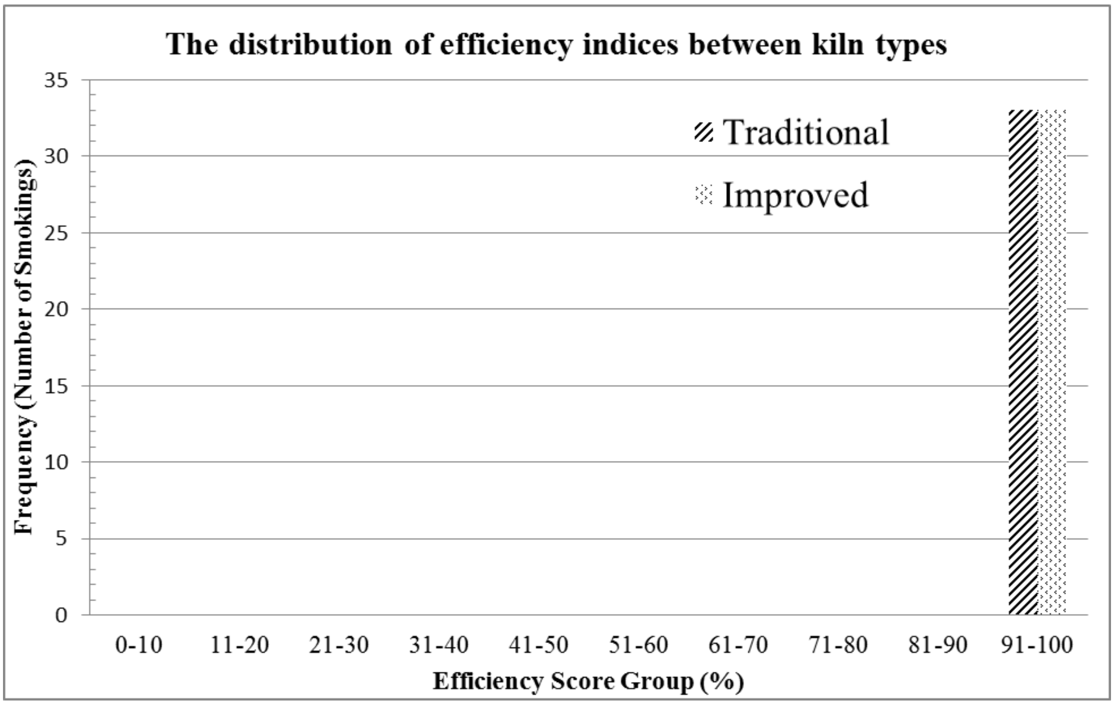

Figure 4.1: Frequency Distributions of Technical Efficiency Score

4.6 Avoided Deforestation Estimates

The study results showed that there is no differential in the usage of firewood between traditional and improved fish smoking kilns. Consequently, there is no evidence that a certain amount of deforestation would be avoided by using one of the methods instead of the other.

CHAPTER 5

CONCLUSSION AND POLICY RECOMMENDATIONS

5.0 Conclusion

The study set out to provide comparative performance analysis of fish smoking kilns and its associated impact on the forest resource in the Lake Chilwa basin. The objectives of the study were two-fold; first, the study aimed at determining whether or not there were differences in the mean technical efficiency levels between traditional and improved kilns. Second, the study sought to establish the extent of deforestation that would be avoided in a year by using a more efficient kiln type. In order to achieve the two objectives, the study collected data through field experiments and semi-structured questionnaires.

Before examining the two study objectives, log-likelihood test was used to conduct diagnostic tests to ascertain the correct functional form that best captures data for the two types of fish smoking kilns. The same test was also used to ascertain the presence of technical inefficiencies in the kiln models. The study showed that transcendental logarithmic production function adequately represents data for traditional kilns whereas Cobb-Douglas was the correct functional specification for improved kilns. The study also showed that there was no evidence of technical inefficiencies in both traditional and improved kiln models. A pooled regression for both types of kilns was also estimated and the diagnostic tests indicated that Cobb-

Douglas was the correct functional form and that there was no evidence of technical inefficiencies in the pooled model.

The study showed that the traditional kilns do not use more firewood than improved kilns to smoke a given quantity of fresh fish. On the other hand, the study has shown that traditional kilns use more labour than improved kilns. Consequently, use of the later can divert human resources to other productive ventures.

In terms of the extent of deforestation that would be avoided by using the more efficient kiln, there is no evidence that forests would be saved.

5.1 Policy Recommendations

The results of the study have shown that improved kilns relative to traditional kilns utilize less labour to smoke a given quantity of fresh fish. Consequently, consistent use of the improved kilns would enhance diversion of human resources to other productive ventures like farming which are also important for the growth of the nation. Thus, it would be recommendable for government to institute deliberate policies to prohibit the use of traditional methods for smoking fish to ensure that the other sectors of the economy have human resource as well. Such policies would include criminalizing all smokers using traditional kilns.

5.2 Limitation of the study

Unlike most of the studies on technical efficiency, this study failed to investigate on determinants of technical inefficiency in fish smoking kilns. By using one smoker for all the experiments, factors like age, smoking experience of the smoker could not be investigated as they were fixed.

Due to funding limitations, the study had no control on the level of moisture retention in the smoked fish. The study funding did not provide for funds to buy fresh fish, specifically for the experiments. All the fish used in the experiments belonged to individual traders. The researcher had to negotiate with individual traders to use their fish for the experiments. Some of them refused to cooperate. Every trader had their own preference regarding the residual moisture level and that the researcher had no control on this. This implied that the comparisons across smoking replications were not as accurate.

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APPENDICES

Appendix 1: Pooled stochastic frontier normal/half-normal model

Number of observations = 66

Log likelihood = 3.4587

Wald chi2 (5) = 7.58

Prob>chi2 = 0.1807

Lnwsfper	Coef.	Std. Err.	Z	P>|Z|	[95% Conf. Interval]	
Lnfwdper	0.0358	0.1916	0.19	0.852	-0.3398	0.4115
Lnlbrper	0.8444	0.3553	2.38	0.017	0.1478	1.5405
Sqfwdper	-0.0124	0.0218	-0.57	0.569	-0.0552	0.0304
Sqlbrper	0.1688	0.1016	1.66	0.097	-0.0303	0.3679
Fwdlbrper	0.0828	0.0688	1.20	0.229	-0.0521	0.2179
-cons	-0.1153	0.5675	-0.20	0.839	-1.2277	0.9971
/lnsig2v	-2.9427	0.1741	-16.89	0.000	-3.2840	-2.6013
/lnsig2u	-13.0672	407.4049	-0.03	0.974	-811.5662	785.4318
Sigma_v	0.2296	0.0199			0.1936	0.2723
Sigma_u	0.0014	0.2961			5.9e-177	3.6e+170
Sigma2	0.0527	0.0091			0.0347	0.0707
Lambda	0.0063	0.2974			-0.5767	0.5893

Likelihood test of sigma_u=0: chibar2(01)=0.00 Prob>=chibar2=1.000

Appendix 2: Traditional smoking: Stochastic frontier normal/half-normal model

Number of observations = 33

Log likelihood = 6.3080

Wald chi2 (5) = 13.17

Prob>chi2 = 0.0219

Lnwsfper	Coef.	Std. Err.	Z	P>|Z|	[95% Conf. Interval]	
Lnfwdper	-0.0167	0.2342	-0.07	0.943	-0.4758	0.4423
Lnlbrper	1.4810	0.4626	3.20	0.001	0.5744	2.3877
Sqfwdper	-0.0537	0.0362	-1.49	0.137	-0.1245	0.0172
Sqlbrper	0.1000	0.1497	0.67	0.503	-0.1932	0.3937
Fwdlbrper	0.2828	0.1287	2.20	0.028	0.0306	0.5350
-cons	0.2112	0.6103	0.35	0.728	-0.9841	1.4081
/lnsig2v	-3.2203	0.2465	-13.06		-3.7034	-2.7371
/lnsig2u	-11.4621	133.0142	-0.09		-272.1651	249.2409
Sigma_v	0.1999	0.0246			0.1570	0.2545
Sigma_u	0.0032	0.2157			7.95e-60	1.32e+54
Sigma2	0.0399	0.0099			0.0206	0.0593
Lambda	0.0162	0.2184			-0.4118	0.4442

Likelihood test of sigma_u=0: chibar2(01)=0.00 Prob>=chibar2=1.000

Appendix 3: Improved Kilns: Stochastic frontier normal/half-normal model

Log likelihood = 4.6189

Number of observations = 33

Wald chi2 (9) = 6.38

Prob>chi2 = 0.2713

Lnwsfper	Coef.	Std. Err.	Z	P>|Z|	[95% Conf. Interval]	
Lnfwdper	0.6037	0.5181	1.17	0.244	-0.4117	1.6191
Lnlbrper	1.5263	0.7421	2.06	0.040	0.0719	2.9807
Sqfwdper	0.0237	0.0408	0.58	0.561	-0.0562	0.1037
Sqlbrper	0.1842	0.1543	1.19	0.233	-0.1182	0.4867
Fwdlbrper	0.1649	0.1050	1.57	0.116	-0.0408	0.3707
-cons	2.3021	1.7599	1.31	0.191	-1.1473	5.7515
/lnsig2v	-3.1178	0.2468	-12.63	0.000	-3.6015	-2.6341
/lnsig2u	-12.4684	550.7788	-0.02	0.982	-1091.975	1067.038
Sigma_v	0.2104	0.0259			0.1651	0.2679
Sigma_u	0.0019	0.5401			7.6e-238	5.1e+231
Sigma2	0.0442	0.0109			0.0227	0.0658
Lambda	0.0093	0.5425			-1.0539	1.0726

Likelihood test of sigma_u=0: chibar2(01)=0.00 Prob>=chibar2=1.000

Appendix 4: Experimental Design (Study Tool 1)

1. The fish smoking experiments will be conducted at Swang'oma Beach in Phalombe District. Two blocks of experiments will be concurrently set up; one for smoking fish using the traditional method and the other using improved kiln.
2. The experiments will be replicated for 33 times for the data to be statistically reliable.
3. After initial sun-air drying on the racks, fresh fish to be smoked will be weighed to obtain weight of fish before smoking.
4. The fish will then be split into two approximate equal proportions; so that one proportion is smoked on open fire and the other on improved kiln.
5. Firewood pieces of equal sizes (known volumes, m^3) will be used on either kiln type. Total volume of firewood used to smoke fish in each type of kiln will be recorded.
6. Fish smoking will start at the same time on both kilns and starting time will be recorded; similarly, finishing time for smoking on each kiln type will also recorded. Thus, total time taken to smoke the fish on each kiln type (in hours) will be calculated;
7. Labour hours for smoking fish on each kiln type will also be recorded. This will include time taken to place the fish on the rack for initial sun drying, re-inserting firewood (kusokhezera), turning the fish for even-smoking and rotating the fish wire meshes on the improved kilns. For each activity (e.g. fish turning), time estimate for a single occurrence will be estimated; and during the experiments, we will record the number of times an activity is done, from which an estimate of total labour hours for that activity will be calculated.
8. The smoked fish from each kiln will be weighed to obtain weight after smoking; thus moisture loss due to processing will be calculated.
9. All fish smoking will be done by the same person who is competent in using each of kiln type.

Appendix 5: Semi-Structured Questionnaire (Study Tool 2)

PERFOMANCE OF FISH SMOKING KILNS AND ASSOCIATED IMPACT ON FOREST RESOURCE: Case Study of Lake Chilwa Basin

Questionnaire Number: ______

A. IDENTIFICATION

Date of interview	
District	
T/A	
Village	
Name of Fish Smoker	
Name of Kiln Owner	
Type of Kiln	1 = Traditional kiln 2 = Improved Kiln

B. SOCIO-ECONOMIC BACKGROUND OF THE FISH SMOKER

Question	**Codes**	
B1. Gender	1 = Male 2 = Female	
B2. Age (Years)		
B3. Level of education	1 = None 2 = Adult literacy 3 = Standard 1 to 4 4 = Standard 5 to 8 5 = JCE 6 = MSCE	
B4. Marital status	1 = Married 2 = Widowed 3 = Divorced/Separated 4 = Never married	
B5. Do you permanently live here or you come and go?	1 = Migrant fish smoker 2 = Permanent resident	

B6. If migrant fish smoker, where did you come from?		
B7. Main occupation	1 = Farmer 2 = Fisher 3 = Hunter 4 = Fish trader 5 = Fish processor 6 = Formal employment 7 = Business/ petty trading 8 = Student	
B8. Secondary occupation	1 = Farmer 2 = Fisher 3 = Hunter 4 = Fish trader 5 = Fish processor 6 = Formal employment 7 = Business/ petty trading 8 = Student	

C. FISHING PROCESSING

C1. For how many years have you been smoking fish?

C2. Which months of the year do you consider as:

i. Peak months

Codes

1=Jan	2=Feb	3=Mar	4=Apr	5=May	6=Jun	7=Jul	8=Aug	9=Sept	10=Oct	11=Nov	12=Dec

ii. Off- Peak months

Codes

1=Jan	2=Feb	3=Mar	4=Apr	5=May	6=Jun	7=Jul	8=Aug	9=Sept	10=Oct	11=Nov	12=Dec

	C3. Which fish species do you smoke in these months? **Codes** 1 = Chambo 2 = Kasawala 3 = Milamba 4 = Other (Specify)	C4. Daily quantity of fish processed? **Unit Codes** 1 = Plates 2 = Dozens 3 = Baskets 4 = Other (specify)		C5. Total hours spent in fish smoking in a day	C6. What is the purchasing price of fresh fish? **Unit Codes** 1 = Plates 2 = Dozens 3 = Baskets 4 = Other (specify)		C7. What is the selling price of processed fish at the processing site? **Unit Codes** 1 = Plates 2 = Dozens 3 = Baskets 4 = Other (specify)	
		Qty	Unit		MK	Unit	MK	Unit
January								
February								
March								
April								
May								
June								
July								
August								
September								
October								
November								
December								

C8. Source of Firewood **Codes** 1 = buy from local vendors 2 = buy from Dept. of Forestry 3 = own woodlot 4 = Collect from the mountain 5 = others specify	C9. Type of firewood used for smoking **Codes** 1 = Exotic 2 = Indigenous (Specify the species of wood)		C10. Type of firewood they prefer to use for fish smoking **Codes** 1 = Exotic 2 = Indigenous (Specify the species of wood)		C11. Reasons for the firewood type preference **Codes** 1 = less emission of smoke 2 = imparts good flavour to the fish 3 = slow burning wood 4 = available firewood 5 = others (specify)	C12. Quantity and monetary value of firewood used in a day	
	Type	Name of wood species	Type	Name of wood species		Qty	MK

D. ADDITIONAL INFORMATION (To be obtained from Kiln Owners)

Question		
D1. Total number of Kilns	Improved Kilns	
	Traditional kilns	
D2. For how long have you had the kilns?		
D3. How much did it cost you to construct each kiln	1 = 1000-3000 2 = 3001-5000 3 = 5001-7000 4 = 7001-9000 5 = Above 9000	

D4. How often do you maintain the following	**Kiln Oven:** 1 = Never 2 = Every 6 months 3 = Every year 4 = Every 2 years 4 = Other (specify)	
	Wire Trays: 1 = Never 2 = Monthly 3 = Every 2 months 4 = Every 3 months 5 = Every 6 months 6 = Every year 7 = other (specify)	
D5. Approximate how much you spend in maintaining the following	**Kiln Oven:** 1 = Less than 500 2 = 500-1000 3 = 1001-3000 4 = 3001-5000 5 =Above 5000	
	Wire Trays: 1 = Less than 500 2 = 500-1000 3 = 1001-3000 4 = 3001-5000 5 =Above 5000	
D6. How much revenue do you get per day from renting out of kilns during	**Peak months** 1 = Less than 500 2 = 500-1000 3 = 1001-3000 4 = Above 3000	
	Off-Peak months 1 = Less than 500 2 = 500-1000 3 = 1001-3000 4 = Above 3000	
D7. Do you have any experience in fish smoking?	1 = Yes 2 = No	

D8. If yes, how long is the fish smoking experience		
D9. What qualities do you look for in fish smokers who rent your kilns	1 = None 2 = Should be women 3 = Only experienced smokers 4 = Other (specify)	
D10. Do you have any influence on the duration the fish smokers take per trip?	1 = Yes 2 = No	
D11. If yes, what influence?		