

**FACTORS AFFECTING THE TECHNICAL EFFICIENCY
OF BORO RICE PRODUCERS OF NORTHERN
REGION IN BANGLADESH**



**A THESIS SUBMITTED FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY**

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A yellow scroll with a black outline, featuring a wavy left edge and rolled-up top and bottom edges. The text is written in a blue, stylized font in the center.

*Dedicated
To
My Parents*

DECLARATION

I hereby declare that the research work embodied in this thesis entitled “**FACTORS AFFECTING THE TECHNICAL EFFICIENCY OF BORO RICE PRODUCERS OF NORTHERN REGION IN BANGLADESH**” has been carried out by me for the degree of **Doctor of Philosophy** under the guidance of Supervisor, **Dr. Provash Kumar Karmokar**, Professor, Department of Statistics, University of Rajshahi, Bangladesh.

I also declare that the result presented in this dissertation is my own investigation and any part of this thesis work has not been submitted to elsewhere for any degree/diploma or for similar purpose.



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CERTIFICATE

It gives immense pleasure to certify that **Mr. Ranjan Kumar Kundu**, Ph.D Fellow, Department of Statistics, Roll Number: 13221, Session: 2013-2014, University of Rajshahi has completed his dissertation titled **“FACTORS AFFECTING THE TECHNICAL EFFICIENCY OF BORO RICE PRODUCERS OF NORTHERN REGION IN BANGLADESH”** under my supervision.

It's an original research work performed by Mr. Kundu with his own effort.

I wish him all success.


29.06.2021

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The Author

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ABSTRACT

Because of its significant contribution to the development of various economic-related activities and self-sufficiency in food production, agricultural production needs to increase under the existing challenges so far. Despite increased rice production, it is evident that among all varieties, Boro rice is contributing the largest share of Bangladesh as well. The satisfactory contribution in the production of Boro rice has been unearthed for the Northern regions of the country in this respect. As therefore, investigation of determinants of production risk and efficiency and /or inefficiency may have an important role based on the stochastic production framework. According to the objectives, an attempt has been made to examine the contributory impact of the assigned input variables using frontier modelling. Firm-level primary data of 350 Boro farmers have collected from Rangpur, Dinajpur, Bogura, and Natore districts using an appropriate sampling technique and choice of functional form, distributional assumptions of models.

Together with different preliminary statistics related to the research, technical efficiency has computed using Stochastic Frontier Modelling for selected Upazilas and districts. Small unit efficiencies have been computed for the eight Upazilas. The Farmers' Performance Indicators on the integrated management in the efficiency ground has been investigated under the Half-Normal assumption of errors of districts as well as the pooled data. Since agricultural loans may have an influential impact on the development of small farmers in their ability for the adoption of agricultural support systems to enhance productivity, eight SFA models of loan receiving and non-receiving categories have fitted. Together with these, how significantly reduces production (in)efficiency by this parameter has been examined. Although the Loan-receiving groups of Rangpur and Dinajpur districts are significant, it is insignificant for the Non-Loan receiving groups. The opposite results for Bogura and Natore are evident. However, the mean efficiency of the Loan-receiving group decreases in comparison to the Non-receiving group for Rangpur and Dinajpur but the different figure founds for Bogura and Natore. Further, inefficiency effects have been tested for different null hypotheses and the differences between Loan and Non-Loan groups of Natore and

Bogura districts have found while for the districts Rangpur and Dinajpur no such equal contribution of variables for both Loan and Non-Loan group have discovered. Further, inefficiency under the Error Frontier Modelling was estimated as 94% and 96% technical efficiencies for Rangpur and Dinajpur. Hence, the Boro production yet to improve 6% following technological changes without increasing the input levels for Rangpur and the improvement chance of Boro producers is 4% for Dinajpur. However, no such scope of improvement for the producers by inefficiency model as the efficiencies of the districts Bogura and Natore. The variations in the Boro output of the frontier model are characterized and confirmed by formal tests. The goodness of fit and correctness of distributional assumption of the errors of the Natore district, the most diseases and pest affected in Boro farming has identified by the insignificance of the parameter gamma (γ) approximately equals to unity. Similar effects of the Boro producers of Bogura are identified. The estimated coefficients of the pooled data are found statistically significant with a positive contribution to the Boro production. The likelihood chi-square for variance parameter is significant indicating the appropriateness of using the inefficiency model for the analysis. Even though 91% technical ability of farmers confirms by the mean efficiency, the remaining 9% output loss may happen due to the inefficiency parameters either for difference of farming practices or for the inefficiencies among the sample farmers, or both.

As it is easier to confine the underlying properties of cross-sectional data by constructing the JLMS estimates towards the shrinkage, assuming input indicators are independent mean efficiency scores also have computed in this research. The district, Natore shows the minimum mean efficiency among the districts and Bogura shows its efficiency as unity while the minimum JLMS records show the gradually increasing trend from Natore to Dinajpur except for Bogura due to the fully efficient model. The result validates by sophisticated modern tests. Finally, the output of the study and the parameter of the technological changes beyond controlled variables will help to mitigate the existing demand of food for the Northern region as well as Bangladesh could be an important message for the policy makers and concerning authorities in this regards.

CHAPTER I

INTRODUCTION

INTRODUCTION

1.1. Background

Like most of the developing countries, agriculture sector of Bangladesh plays a significant role in the economy by contributing 13.35 percent to Gross Domestic Product (GDP) in the financial year 2019-20 and occupies about 40.62 percent share of total labour forces (BER, 2020). Bangladesh is the eighth densely populated country in the world, having a population of over 166 million with an area of 147,570 Square Kilometre. The majority of her population are directly or indirectly involved in agriculture related activities for their livelihood. At present, the total agricultural household family of the country is about 16,562,974 and at the same time, the gross cultivable area is around 16.06 million hectares. Nearly 8.13 million hectares of land are under net cultivation and 0.43 million hectares are cultivable fallow (BBS, 2020). Among the crops, rice is widely cultivated all over the country throughout the year. Soil and climate of the country is suitable for rice cultivation and for this reason rice is considered as the staple food of Bangladesh population. Rice is the major cereal crop that covers around 77 percent of the total cropped area (10.43 million hectares) and contributing to 95 percent of the total food grain production. Around 70% intake of the human calories and 58% protein in the country is supplied by rice (Mottaleb and Mishra, 2016). The per capita consumption of rice in Bangladesh is very high, which exceeds 170 kg annually. Due to gradual increase in the number of population, the demand of rice is also increasing significantly. Now Bangladesh included herself within the first fourth position as rice producing country in the world (FAOSTAT, 2019) and its consumption position is four. In Bangladesh, rice is cultivated three times in a year and it is classifying into three varieties like Aus, Aman and Boro. Aman rice is planted in the field at monsoon period and harvested in mid to late

autumn. But, Aus rice is planted during May-June and harvested in the August-September. On the other hand, due to high production Boro is very popular in the country. The Boro rice is planted during November - December and harvested in March-April. To increase the total production of rice the government of Bangladesh invested it's all out efforts, because the increased production helps the government to ensure the food security for all the population of the country. From the inception of our independence in 1971, production of rice increased over three folds. Rice is the driving force of Bangladesh agriculture and in fact, food production in Bangladesh is dominated by rice especially Boro rice. It alone contributed to the highest share of total rice production since 1998-99 to date, which accounts for over 60% of total production. Therefore, increase of Boro production is a significant possible way to face food deficiency in the country. The average yield of rice is 4.22 metric tons (MT)/hectare in Bangladesh whereas the yield in of Japan and China are 6.83 and 7.06 MT/hectare respectively (FAOSTAT, 2019). In Bangladesh, both food security and socio-political stability are center around rice farming and its activity. During in 1950's as well as in 1960's and even in 1970's when population of Bangladesh (in that time East Pakistan) were not more than 70 million, widespread hunger and frequent famine situation was common. In 1971, around 17 million tons of rice produced under about 10 million hectares of land and then yield of clean rice was 1.05 MT/hectare. The population has increased to well over 162 million and rice production reached to 4.32 MT/ha by 2012-13. It indicated that the production of rice increased almost three and half times over the last 4 decades. The rapid urbanization enhances the housing facilities for the increased populations caused run out of the cultivating lands. If the present population growth rate continues, population of the country will be about 189 million by 2030 and demand for rice will be 18 percent higher than that of the present production level. Boro rice grows entirely in the dry season under irrigated condition of our country. Seedbeds are prepared from October

to December, seedlings are transplanted in the field from December to February, and finally the crop is harvested from late April to June. Nearly 91.77% of the total cultivated area of Boro rice (4.08 million hectares) is covered by modern varieties. As the winter is relatively free from insects and diseases, and availabilities of higher solar radiation along with better water management, the yields of the Boro rice is higher than any other seasons.

To enhance total production of rice significantly modern technology can be used and investment on research is essential under new technologies. In last three decades due to proper attention on rice research and farming by the government total production is growing to meet the additional needs. Increased rice production is related to attain the Government's 'Vision 2021' to be a middle-income country and also for achieving the Sustainable Development Goals.

In the last decade, the government of Bangladesh undertakes pragmatic and multidimensional steps to increase domestic production of rice to attain the self-sufficiency in food production as well as and develop a good reserve to mitigate any emergency in this regards. Some of these interventions are providing subsidies in agricultural inputs like chemical fertilizers, irrigation equipment, fuels, insecticides, pesticides, etc. and at the same time making these items readily available to the farmers. Besides, the government has put emphasis on training of farmers and transfers of technologies, and also the procurement of domestic rice for encouraging the grower. As a result, the domestic production of rice increased significantly and the country is at the doorstep for attaining self-sufficiency in rice production. Efficient use of modern production technologies in Boro seasons can reduce the cost and increased the production significantly which ensures the efficient use of available resources for maximum output.

Even if government of Bangladesh has introduced several pragmatic interventions to accelerate the production of rice some uncontrolled causes like risks of drought, flood, cyclone, salinity intrusion and many other disasters/natural calamities are working against the farmers and their production. Adoption of improved technologies and some hidden parameters besides the traditional inputs may have the causal effect in the development of the Boro production of the country. As such, the author has intended to investigate the (in)efficiencies of Boro farmers of the Northern region of Bangladesh in this regards.

1.2. Problem statement

As a cereal crops rice is very important in the world and its rank is the third followed by wheat and maize. About 90% more of global production alongwith consumption of rice takes place in the Asia-Pacific region (Fatima *et al.*, 2018) where as about 50% of the world population take it as their staple food. Hence, rice production is the key to global food security in Asia as well. The growth in rice production with stability has been a matter of concern to achieve food security, especially in developing countries (Bandumula, 2018). As an agro-based developing country Bangladesh faces challenges in achieving food security due to its high population, limited cropland and cropping intensity (Timsina *et al.*, 2018). Bangladesh is the fourth largest rice producing country in the world following China, India and Indonesia (FAOSTAT, 2019). To achieve sustainable long-term self-sufficiency of food-grain production in Bangladesh, it is very important to increase the production of rice, particularly Boro rice. Moreover, in Bangladesh productivity of rice still has been relatively low compared to other Asian countries, such as Indonesia, Vietnam, Japan, South Korea, North Korea, Taiwan and China (FAOSTAT, 2019). As such, to increase the rice production of Bangladesh, it is important to identify the key factors as influential to Boro production.

Therefore, the effective way is to improve Boro productivity by ensuring proper utilization of the inputs in the production process. For sustaining and increasing Boro production, along with technological improvements, an increase in efficiency of the farmers is indispensable. Thus, technical efficiency critically important in producing Boro rice and therefore proper utilization of agricultural inputs will continue to increase during the coming decades. As therefore, it need to focuses on the improvement of Boro farmers' efficiencies under existing resources as well as adoption of better technologies.

Moreover, investigating factors that influence efficiency of farmers as key variables could be helpful in policy-making on the optimal resource utilization ground. As an emerging tiger in the world, Bangladesh needs to continue such progress to meet the challenges for the required food security and sustainable supportive information could be achieved through the identified factors suitable to the (in) efficiency of Boro producers under the topic, "Factors affecting the technical efficiency of Boro rice producers of Northern region in Bangladesh".

1.3. Research questions

A pertinent question is how to increase the Boro productivity in Bangladesh? Production of Boro rice can be increased in three possible ways as- i) by allocating more land for rice production, ii) by adopting new technologies and iii) utilizing the available resources more efficiently. However, there is no scope for horizontal expansion of the rice area, so it is the greatest challenge to the policy makers and concerning authorities. Adoption of new technologies requires huge amount of investment.

In this research the questions can be stated as-

- i) what are the socio-economic and demographic characteristics of Boro producers?
- ii) what are the factors that determine levels of Boro yield in the Bangladesh?

- iii) what is the level of efficiency of Boro producers to catch up the output frontiers?
- iv) what are the influential factors that may contribute to (in)efficiency and constraints faced by the Producers?

1.4 Research hypotheses

Based on the proposed study of factors affecting the technical efficiency of Boro rice producers of northern region in Bangladesh and the defined objectives of the study tested the following assigned five hypotheses. In the suitable cases, appropriate form of the Cob-Douglas production functions of the data or logarithmic values of data are considered as an adequate representation model.

Hypothesis 1: Boro rice producers in northern region are not technically inefficient and no production loss is attached to technical inefficiency of Boro rice producers.

Hypothesis 2: Both the parameters of the stochastic frontier and the inefficiency model are jointly zero such that the variables to be used may affect inefficiency of the Boro rice producers in northern region.

Hypothesis 3: There is no such discrepancy between the Loan and Non-loan receiving Boro producers.

1.5. Motivation and relevance of the study

As an agro-based country, Bangladesh people certainly depend on agricultural production for food and calories of her population and there are about 13.35% of the country's GDP is coming from the agricultural sectors. Boro rice constitutes maximum shares among all the varieties, and from the economic ground, the allied indicators or variables may have a significant role in this regard. Therefore,

measuring technical efficiency and the subsequential performances is an urgent issue to the farmers and the policymakers for their economic betterment. How the output could be influenced by simply increasing the levels of efficiency without considering further resources besides the assigned obligatory variables from the cultivating strategies is a matter of investigation in this situation have tried to understand. The potential factors affecting technical efficiency may be the parameter to address productivity gains by improving allied characteristics for farm management practices could be evident from this empirical study.

Despite the limitations, hope the contribution of this study would be unique and could be helpful for the households and policymakers in decision purpose related to productivity by providing information on crop diversification and technical efficiencies for the concerning authorities of the country.

1.6. Significance of the study

As far as the knowledge goes, no empirical study has been conducted to measure the technical efficiency, and identify the factors that affect the technical efficiency of Boro rice producers of northern region in Bangladesh. Therefore, it could be confirm that, the present study is a pioneer research on the analysis of technical efficiency of Boro rice producers in the northern region of Bangladesh. Furthermore, the study had also been investigated some of the determinants of technical efficiency among the Boro rice farmers in the study area which were not examined in any other previous studies. Measuring technical efficiency of the growers provide a way for quantifying and comparing the performance of each individual farmer, and at the same time identification of the factors that explaining any inefficiencies and differences in respect of performance. Identification of factors affecting inefficiency can assist stakeholders to improve the productivity, and to identify controllable and uncontrollable factors that affect efficiency, which are needed to be taken into

account in designing the interventions. The findings of this study will be important and useful to Boro rice growers for increasing the productivity and performance of production. The output of the study would also help making able to use of the available opportunities and to eradicate the constraints in Boro rice production. Moreover, the empirical evidence from the study may be essential for policy makers towards better, rational and well-versed decision-making in formulating appropriate policies, strategies, programs and interventions that help increasing Boro rice production and productivity. The action consequently enhance the achievement of the national goals for reducing poverty by improving rural income and achieving long term sustainable food security in Bangladesh. Besides, the document also may serve as a reference for researchers and academicians to embark upon similar or related works in other parts of the country. Finally, the findings of this study would help filling the knowledge gap which was identified during literature review.

1.7. Aim and objectives

The determinants of Boro producers' technical efficiency (TE) of Northern region in Bangladesh focusing on the impact of some variables to be investigated within the existing technologies under following aspects.

- To have an idea about the Boro production of Northern region of Bangladesh.
- To analyze input, socio-economic and demographic variables to determine the farm-specific efficiency and farmers' performance indicators.
- To examine TE and its determinants referring to the potential inputs through stochastic frontier production function.

- To assess the impact of various distributional assumptions on technical efficiency level of farmers for identifying the major constraints and make comparison among the Small Unit efficiencies.
- To investigate the integrated management of the farmers as the contributory variables influencing (in) efficiency with the help of SFA modeling and to identify and rank the constraints of the Boro producers.

1.8. Scope of the study

The most important motivation for production improvement in most developing countries is needed to raise productivity through technical efficiency, where resource constraints are of major problems that also increases effectiveness of technological adoption in the long run. Therefore, to achieve such objective an empirical study is required to analyze technical efficiency of farmers. Having such insight, the focus is being placed on Boro rice producers in the northern region, the foremost producers of rice in Bangladesh. The focus on the northern region is being motivated by the fact that production of rice is subjected to high fluctuations in relative to another region of Bangladesh producing rice crop. Moreover, evidence from many empirical findings show that efficiency study may be given priority setting in case where production reveals high fluctuations provided that productivity is relatively lower. Given resource at hand and the reasons stated, therefore, the study is delimited to sample size of 350 Boro rice producers in the northern region of Bangladesh during the period of 2018-2019 Boro rice producing season.

1.9. Limitations of the study

Focused on the analysis of TE of Boro farmers using SFA and the factors causing efficiency variation among farmers by utilizing the inefficiency model are investigated in a limited area of northern region, Bangladesh.

The findings of the study could be viewed in light of some potential limitations. Although the study was conducted through the random selection of samples of four districts out of sixteen, generalization of region, farmers and variety of crops were not considered is a limitation of the study.

The study uses a cross-sectional data generated from 350 sample farmers. As cross sectional data reflect farmers' circumstances in a given year, specific climate of the year may affect the result due to the dependent of agricultural weather. Moreover, the result of cross-sectional data does not show differences of producers' efficiency levels. These may be a kind of limitation and verification in a wider scale have not accomplished is also a limitation of the study.

1.10. Organization the dissertation

The study consists of seven chapters including the introduction given in the Chapter One. Chapter Two focuses on global as well as domestic overview of rice production. Chapter Three provides the review of literature related to the research topic. Chapter Four describes the data and the research methodologies followed by the Chapter Five includes the Models and Small Unit Efficiency and the Chapter Six demonstrates the Farmers' Performance Indicators of the study area. Both the Fifth and Sixth chapters comprise the detailed results devoted to the presentation and interpretations. The conclusions and policy implications in these research contains in the Chapter Seven. Finally, the dissertation ends by the list of references and appendices.

CHAPTER II

OVERVIEW OF RICE PRODUCTION

OVERVIEW OF RICE PRODUCTION

2.1. Introduction

Since Boro production concerned information is very essential for the producers, this chapter highlighted the importance, overview of rice production and its local and world importance accordingly followed by the current rice situation and its perspectives.

2.2. Rice scenario around the world

In the low-income countries most of the population mainly depends of rice as a cheap sources of carbohydrates to meet energy requirements. The increasing pattern of growth rate of rice and demand against the supply the cereal demand scenario are becoming more complicated. The global rice production, trade, consumption and as well as its importance in the above ground are discussed herewith.

2.2.1. Global importance of rice

Rice is the livelihood of huge community as because it is somehow considered as a truly life, a culture, a tradition of such supreme commodity to mankind (Nain *et al.*, 2019). In the cereal list nowadays it is the second important crop in the world and serves as a staple food source for more than half of the world's population that influences the economic activities of several billion people. As a staple diet by more than 60% of the global population are consuming more than 3 billion people with the amount of 100 kg per year (Fukagawa and Ziska, 2019; Muthayya *et al.*, 2014). Due to its high adaptability and productivity, the cultivation of rice spread rapidly around the globe and is currently being produced in almost all the tropical and subtropical regions of the world (Yusuf *et al.*, 2019). More than half of the population are taking rice as main food in the world. It is the predominant food source for 17 countries in

Asia and the Pacific, nine countries in North and South America, and for eight in African continent. According to USDA data, early 1990s, the amount of rice production was about 147 (million ha) globally but the last century total production was about 520 million MT, thereafter it was 594 million MT from 1523 million hectares and at the end of the next decade it was 672 million MT from 158 million hectares. Now this annual production reached more than 728 million MT from about 162 million hectares every year around the world. Including the Caribbean people Rice is the vital source of nutrition of much population in Asia, Africa and Latin America. It is providing 66% to 70% body calorie intake of the consumers in the world (Nain *et al.*, 2019). Rice also provided 19% of global human per capita energy and 13% of per capita protein. Asia accounts for 90% of global rice consumption and total rice demand there continues to rise. Although it is not the staple food in many countries of Africa and Latin America, per capita consumption is increasing. The world will need about 904 million MT of rice by 2030 to meet the growing demand (Kubo and Purevdoj, 2004).

2.2.2. Overview of global rice production

Rice is grown around the continents of the world, except Antarctica. As the global food, it has a large influence on human nutrition and food security all over the world. World rice production is spread across at least 114 countries (FAO, 2019) and rice is grown on 144 million farms harvested in near about 162 million hectares worldwide—more than for any other crop. Among the productions about 90% of the global harvested rice produced in Asia, 3.4% in South America, 4.2% in Africa, 1.8% in North America and only 1% in Europe and continental production harvested area and yield of rice are given in the Table 2.1 below.

Table 2.1: Rice production, harvested area and yield by continent

Continent	Production (MT)	Harvested Area (ha)	Yield (MT/ha)
Asia	667,258,311 (90% of global rice harvest)	144,251,532	4.6257
South America	24,941,895 (3.40% of global rice harvest)	4,812,416	5.1828
Africa	31,194,241 (4.20% of global rice harvest)	11,586,465	2.6923
North America	10,025,980 (1.35% of global rice harvest)	1,181,290	8.4873
Europe	4,001,770 (0.5% of global rice harvest)	641,988	6.2334
Oceania	829,990	78,780	10.5355
World	728,066,000	161,616,000.00	4.51

(Source: United State Department of Agriculture, USDA)

In spite of the global rice production exhibited a fluctuating trend in the past few decades; rice production has increased more than three times with a compound growth rate of 2.24% per year. Most of the increase in rice production was due to higher yields, which increased at an annual average rate of 1.74%, compared with an annual average growth rate of 0.49% for area harvested. In absolute terms, rice yields increased at an annual average rate of 51.1 kg/ha per year, although this rate of increase has recently declined in both percentage and absolute terms (Satpal, 2017). At the beginning of the 1960s, rice is cultivated in an area of about 116 million hectares globally, thus giving a total production of about 216 million MT, by the end

of the last century, it was 594 million MT from 152 million hectares and at the end of the next decade it was 672 million MT from 158 million hectares. Now this annual production reached more than 728 million MT from about 162 million hectares every year around the world. In 2017, the global production of rice was 729 million MT and decreased to 728 million MT in the following year of 2018, registering a year on year decline of more than one million metric tons (USDA Data). Trend is given in Figure 2.1.

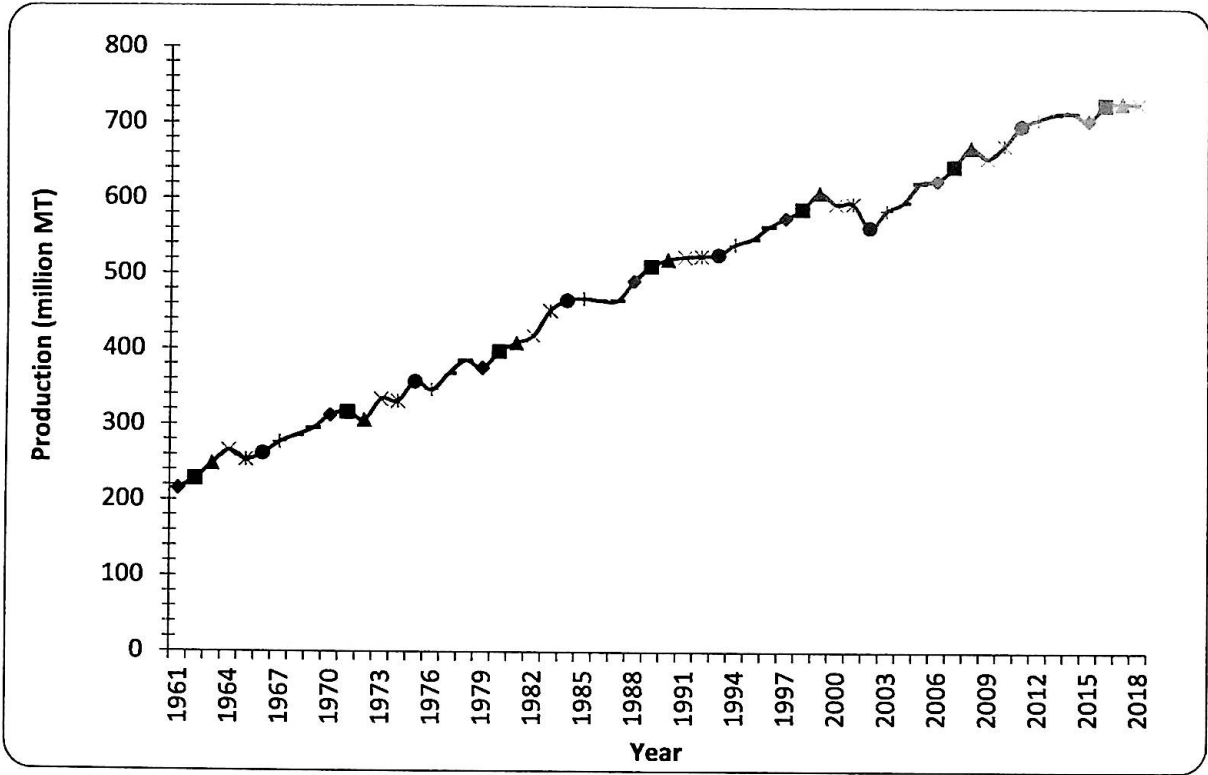


Figure 2.1: Rice production trend in the world.

(Source: United State Department of Agriculture, USDA)

The steadily increased Rice production during the Green Revolution is recently showing downward movement. The Table 2.2 explain that world rice production has continuously increased since 1961, but at varying growth rates. The growth rate was about 45% during the 1960’s, 25% in the 1970’s, 27% in the 1980’s, more than 13% in the end of the last century and first decade of the 21st century. In 2011-2018 global

rice production has increased only 4.26%. During the 1960's the high growth rate of rice production was due to both a high yield growth and a moderate growth in rice area, whereas the rapid rice production growth during the 1980's was due principally to improvement in rice productivity. The growth rate of rice yield was 27% during the 1960's, 17% in the 1970's, about 25% in the 1980's, 10% in the 1990's, more than 8% t in the 2000's and only 3.2% in the 2011 to 2018. The harvested rice area has increased at a decreasing rate since 1961: from about 14.5% per year during the 1960's to only 7.1% t in the 1970's, 1.8% in the 1980's, 3.52% in the 1990's, 4.4% in the 2000's, and only 1.13% in the 2011 to 2018. The trend of harvested rice productivity and its cultivating areas are given in the Table 2.2.

Table 2.2: Area and productivity of rice 1961–2018.

Year	Production (%)	Area (%)	Productivity (%)
1961-1970	44.92	14.54	26.88
1971-1980	25.39	7.10	17.02
1981-1990	27.22	1.80	24.73
1991-2000	13.59	3.52	9.89
2001-2010	13.15	4.41	8.42
2011-2018	4.26	1.13	3.20

(Source: United State Department of Agriculture, USDA)

2.2.3. Global leading rice producing country

By far China is the first leading global rice producing country. Rice production plays an important role in the national economy of China. It produced almost 30% of the total rice production in the world. In 2018, China produced almost 203.143 million MT of rice from 29.5 million hectares rice farming area. India is presumed the world's original country for rice production and is the second largest rice producing country in the globe. Almost 65% of Indians eat rice and many of them are linked with rice production. About 50 million households in India depend on rice production and it is their main source of income. The rice production of India was 163.516 million MT from 43.5 million hectares in 2018 but Indonesia is producing enormous rice and it is the highest rice consuming country. In Indonesia, the per capita consumption of rice per year was 135 kg. Indonesia produced about 58.74 million MT of rice in 2018 from an area of 12.24 million hectares for rice cultivation. Bangladesh is the fourth largest rice producer country in the world. Rice is stapled with their regular food. Almost two-third of the population in Bangladesh links with rice farming and their livelihood totally depends on rice production. Bangladesh produced nearly 52.05 million MT of rice utilizing about 11.77 million hectare area for rice cultivation in 2018. Vietnam is the biggest rice producing country and they are second largest rice exporter country. It is an agro-based country and its economy is actually reliant on rice production. There are the two most famous deltas, including north Red river and south Mekong River where rice is grown. From 7.76 million hectare of rice growing area, Vietnam produced approximately 45.88 million MT in 2018. Thailand exporting rice in the world and it has a significant importance in their economy. Rice cultivation almost takes 55% of the total cultivatable area. According to USDA data rice was grown in Thailand around 32.12 million MT of rice from

11.14 million hectares in 2018. The seventh world's largest rice-producing country is Myanmar. It is also another one of the largest rice exporter countries in the world. Its annual rice consumption per capita annually is almost 510kgs. Myanmar produced approximately 20.94 million MT of rice in 2018 utilizing 7.15 million hectare area for rice cultivation. The Philippines stands eighth global largest rice-producing country. It is an archipelago country which is famous for rice production. Instead of rice production, it also imports rice from other countries. The Philippines produced nearly 19.60 million MT of rice in 2018 utilizing more than 4.850 million hectares area for rice cultivation. It almost imports of 1.8 million MT of rice. Rice consumption in the Philippines is almost 128kg per capita annually. Brazil is the ninth-biggest rice-producing country in the world and is the largest producer outside Asia. In 2018, Brazil produced almost 11.80 million MT of rice utilizing more than 1.96 million hectares area for rice cultivation. Its annual rice consumption is still very low almost 33kgs per capita annually. The tenth largest rice producing country is Japan in worldwide. It is the only industrialized country whose agriculture is based on rice. Rice farming has exerted a considerable influence on the social structure and culture of the country. The rice production of Japan was 10.44 million MT from 7.76 million hectares in 2018. This information is enlisted in the Table 2.3.

Table 2.3: Global major rice producing countries in 2018.

Rank	Country	Production (million MT)	Area (million hectare)
1.	China	203.143	29.500
2.	India	163.516	43.51
3.	Indonesia	58.740	12.243
4.	Bangladesh	52.055	11.770
5.	Vietnam	45.880	7.7640
6.	Thailand	32.121	11.142
7.	Myanmar	20.938	7.151
8.	Philippines	19.603	4.852
9.	Brazil	11.800	1.960
10.	Japan	10.440	7.761
11.	Others	109.830	23.963
	World Total	728.066	161.616

(Source: United State Department of Agriculture, USDA)

2.2.4. Global rice consumption

Currently, rice is one of the leading providers of food calories in the World and it is the most widely used cereal crop today. Asia accounts for 90% of the world's rice, and total rice demand is growing there. However other than Asia per capita consumption is rising. Rice is the fastest growing food staple in Africa and one of the fastest growing foods in Latin America. Global rice consumption remains strong, driven by both population and economic growth, particularly in several Asian and African countries. As the world's most populous country, China consumes more rice than any other country, with 143 million MT consumed in 2018/2019, which equates to close to 30% of global rice production. Following China, India is ranked second and Indonesia is the third consumer of rice in the world and Bangladesh is the fourth. According to USDA, worldwide leading countries based on rice consumption in 2018/19 are given in the Table 2.4.

Table 2.4: Milled rice consumption in 2018-2019.

Rank	Country	Consumption (million MT)
1	China	142.70
2	India	97.35
3	Indonesia	37.40
4	Bangladesh	35.20
5	Vietnam	22.10
6	Philippines	13.00
7	Thailand	11.17
8	Myanmar	9.90
9	Japan	8.45
10	Brazil	8.10

(Source: United State Department of Agriculture, USDA)

2.2.5. Global rice exporting and importing countries

From a continental perspective, three-quarters of global rice exports originated from Asian countries. In the global context, India had the highest export volume of rice worldwide, at 13.0 million MT as of 2018/2019 that accounts about 26.26% of the world's rice exports. Thailand was the second largest rice exporter, with about 11.0 million MT of rice worldwide in that year. After India and Thailand the next largest rice exporting countries are Vietnam, Pakistan, Myanmar, USA, China, Cambodia, Uruguay and Brazil. However about 100 countries of the world import rice. Notable

among these, China, Nigeria, Ivory Coast, Iran, Saudi Arabia, Senegal, Indonesia, Iraq, Bangladesh and Philippines import significant quantities of rice. Twelve countries in Latin America and the Caribbean import more than 4 million MT of rice annually. There are other countries that import rice to meet national food security needs, and these tend to be among the least developed countries of the world. The gap between demand and supply in sub-Saharan Africa, where rice is grown and eaten in 38 countries, reached 16 million MT of milled rice in 2018. Most of the rice consumed in the Pacific Island countries is also imported, with the trade being managed by a handful of importing companies (Muthayya *et al.*, 2014). According to the USDA, the global major ten rice exporting and importing countries are given in the Figure 2.2 and Figure 2.3 respectively.

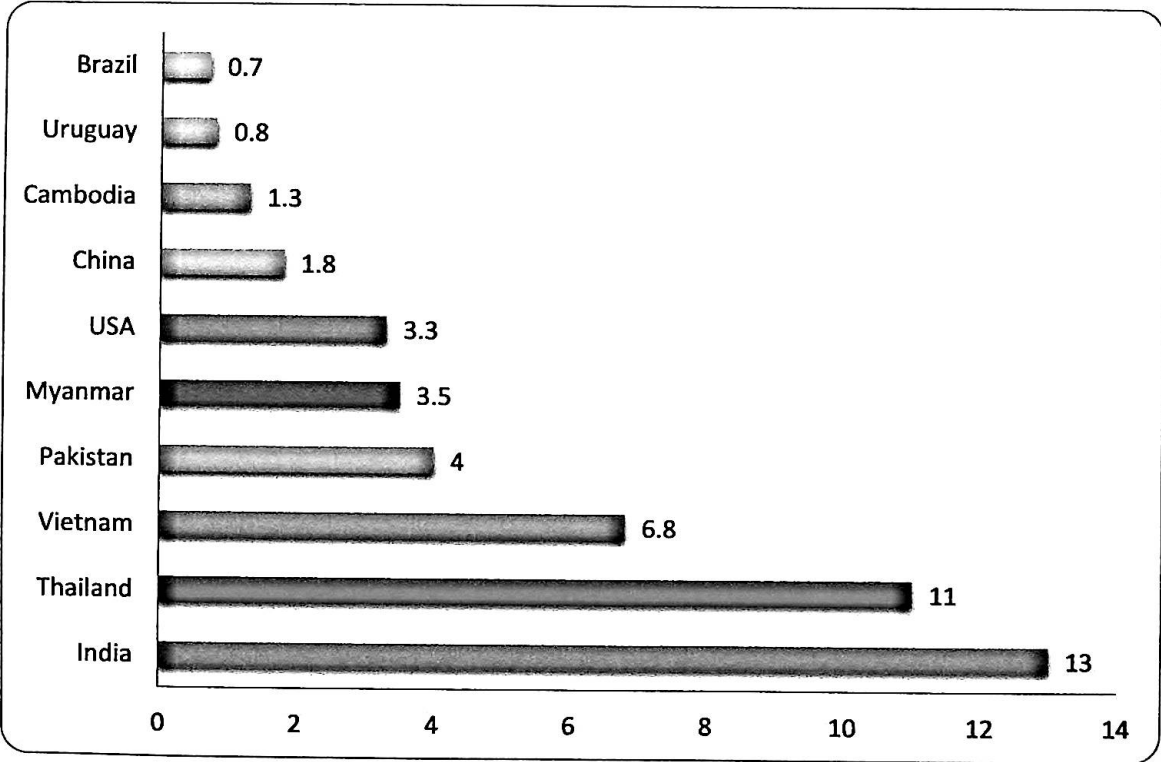


Figure 2.2: Global top ten rice exporting countries in 2018 (million MT)

(Source: United State Department of Agriculture, USDA)

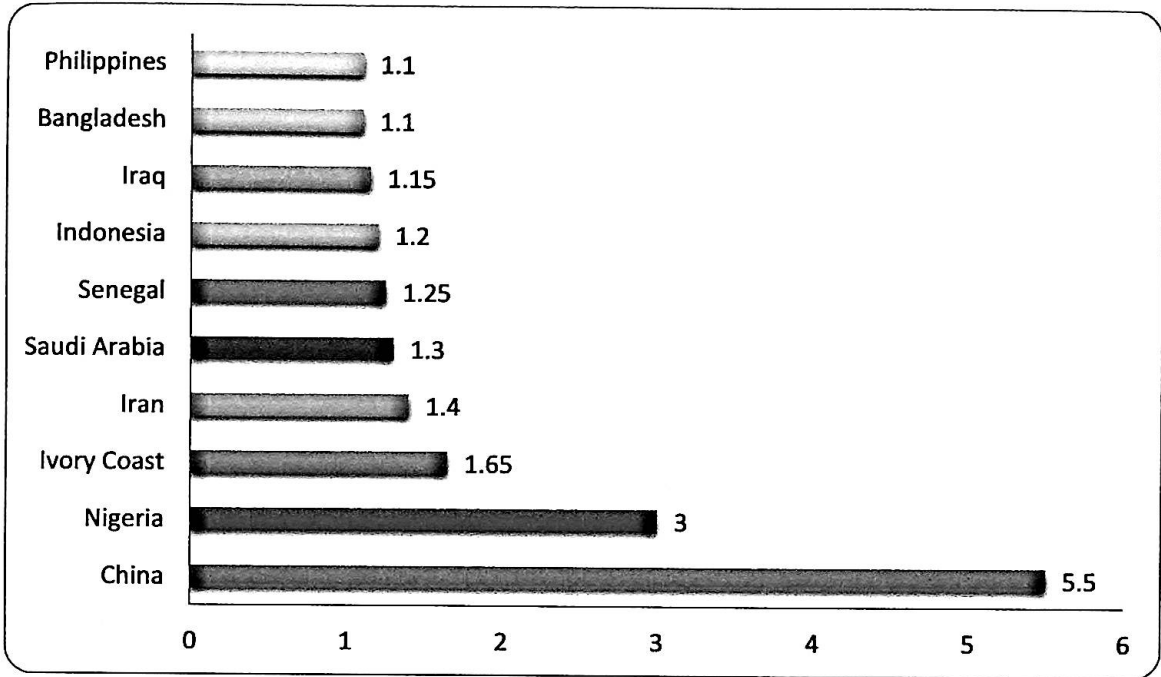


Figure 2.3: Global top ten rice importing countries in 2018 (million MT)

(Source: United State Department of Agriculture, USDA)

2.3. Overview of the rice sector in Bangladesh

This section describes the present scenario of rice particularly Boro rice in Bangladesh.

2.3.1. Importance of rice

Rice is not only a staple food for the people of Bangladesh; they are completely dependent on rice for their survival. It constitutes 95% of the cereals consumed, and supplies about 75% of the calories and 68% of protein in the diet of the population. It also accounts 50% GDP and 50% of the rural employment of the country. It ensures political stability of the country and imparts a sense of security to the people. So rice is often considered as a political and strategic commodity. The culture and heritage of the nation is deeply rooted in rice. Due to socioeconomic, cultural and environmental reasons, the consumption of cereals in Bangladesh is somewhat higher

than the ideal for a nutritionally balanced diet. So, Bangladesh is often branded as Country of Rice. Rice dominates the cropping pattern throughout Bangladesh and it is grown from time immemorial (Nasim *et al.*, 2017, Sharna and Sohan, 2016). Rice farming is deeply involved with food security of household level and national, decline of poverty and hunger, advancement of nutrition and public health, socioeconomic and political stability, and overall growth and development of the developing world like Bangladesh (Roy *et al.*, 2014). In Bangladesh, rice is grown under diverse ecosystem like rain-fed irrigated, and floating or deep water conditions in three distinct overlapping seasons namely Aus, Aman and Boro. Aus is grown under the rain-fed ecosystem during the pre-monsoon period (during March to July) while the second crop, the second crop, Aman is grown under floating or deep-water ecosystem during the monsoon period (during July to December) and the third crop, Boro rice is grown completely under the irrigated ecosystem during the dry period (November to July). Of the total 13.8 million hectares of cultivable land in the country, 10.27 million hectares (75%) are devoted to rice cultivation covering the above three types of ecosystems. Aus accounts for roughly 5% of the total production, Aman accounts for 40 percent, while Boro accounts for 55% of total rice production in Bangladesh (Rahman *et al.*, 2013b).

2.3.2. Area, production and yield trend

Rice is the dominant crop and largely determines the rate of progress in the agriculture sector of Bangladesh. About 75% of the area cultivated by rice and it accounts for about 70% of the volume of crop output. Actually, the entire growth in crop production is due to the growth in food grain production, particularly rice. In the last five decades, great efforts in rice research and farming innovations gave a massive boost to raise both production and productivity of rice.

In Bangladesh, agriculture has made considerable strides in the last few decades. Both production and yields of rice have risen. Production increases have resulted from a substantial intensification of agriculture rather increasing the physical land area available (Maniruzzaman *et al.*, 2019).

During this time, rice production increased a staggering 3.5 times, which jumped from a little over 15 million MT in 1971 to 54 million MT in 2018, making it the fourth largest rice producer in the world. The production of rice was 52.055 million MT in 2018 that is all time high since the independence (BBS). This dramatic increase in rice production has been made possible due to the adoption of modern agricultural technology, policy-making support of the present government, improved varieties and materials and above all the contribution of the hard working farming community. Bangladesh has made steady progress in rice production after independence in 1971. Rice production increased significantly over the years following the introduction of high yielding varieties and application of modern agricultural inputs. Although rice production has been fluctuate in different years due to the diverse climatic phenomena like cyclone, drought, changing rainfall patterns and temperature. The rice production of the country in 1992-93 was 18.22 million MT. In 1993-94 and 1994-95, rice production decreased due to natural calamities in the Northern region that is a surplus grain production region of the country. The average rice production by these two years fell down 18.71 million MT from the average of 19.31 million MT by the past three years from 1990/91 to 1992/93.

Production of rice increased to 313 million MT in year 1995-96 that 289 million MT in 1994-95. Since then the production has been increasing gradually each year and hit 347 million MT in 2003-04.

The actual rice production in 2004-05 was 4.8%, which was lower than that of year 2003-2004 due to crop damages caused by devastating flood and cyclonic rainfalls. However the improving trend started from 2005 and the production of rice was 52.055 million MT in 2018. Moreover, devastating cyclone Sidr in 2007, cyclone Aila in 2009 and cyclone Mahasen in 2013 damaged in agriculture production, especially the rice production. The production area, yield and yield trend of rice in Bangladesh from 1971 to 2018 can be seen in Figure 2.4.

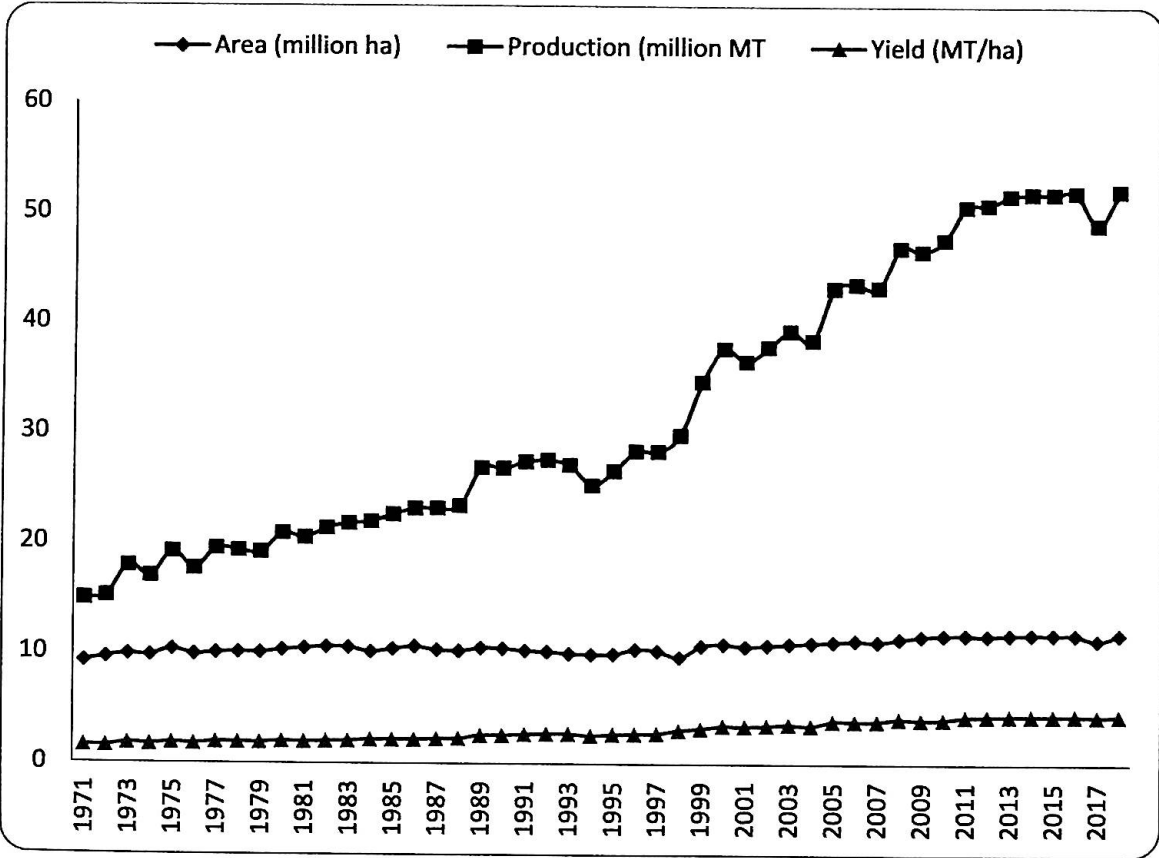


Figure 2.4: Area, production and yield trend of rice in Bangladesh
(Source: Bangladesh Bureau of Statistics, BBS)

2.3.3. Boro rice and its importance in Bangladesh

The Boro, generally known as summer rice or Robi rice and it is seen to be cultivated in the dry-season based on irrigation. The irrigated rice is planted from December to early February and harvested between April and June. This gives the farmers a chance to grow a Rabi crop due to prolonged water stagnation (Shahid *et al.*, 2015). Boro was grown in the very low-lying areas with residual water in the wet season and were irrigated by surface water in times of water shortage (Fujita, 2010). Boro is originated from 'BOROB', a Sanskrit word refers to a special type of rice cultivation in lowlands during November-May months (Singh *et al.*, 2003). In West Bengal and Assam the summer rice is also known as Boro, in Odisha summer rice crop is known as Dalua, in Andhra Pradesh summer rice crop is known as Dalwa, in Kerala summer rice crop is known as Punja, in Tamil Nadu state summer rice crop is known as Navarai and in Bihar summer rice crop is known as Garma (Sekhara and Devarajulu, 2019).

Firstly, in 1967 the modern high yielding rice variety IR-8 was introduced on a small scale in Bangladesh (at that time East Pakistan) agriculture, primarily for Boro using irrigation. Later on beginning in 1970, International Rice Research Institute (IRRI) bred variety IR-20 was introduced to farmers for the Amman season. Since 1973, the Bangladesh Rice Research Institute (BRRI), in partnership with IRRI, has been engaged in adaptive research to evaluate elite genetic lines under the IRRI-managed International Network for Genetic Evaluation of Rice (Shelley *et al.*, 2016). With the increase in irrigation facilities, Boro rice has been emerging as a new cropping system in Bangladesh since liberation in 1971 and is now one of the most popular in Bangladesh. In recent time the most popular Boro varieties developed by BRRI are BR28 and BR29 are cultivated all over the country in favorable conditions and it gives higher yield than other varieties.

Boro is grown in every district of the country. With the spread of small-scale irrigation technology, Boro rice has gained its importance because yields of Boro rice are higher than yields of any other types of rice. This crop now accounts for a disproportionately large share of rice production due to some facilities and integrated crop management approach (Karmokar and Shitan, 2011).

Boro contributes highest share of total rice production utilizing the large portion of cropping area in Bangladesh and out of 37.36 million MT total rice production in 2018-2019, 20.39 million MT found from Boro rice. Boro rice is grown during the dry season (January-May) and cultivated under the irrigation scheme in the northern region and another region of the country.

2.3.4 Trend of area and production of Boro rice

Although Boro rice has played an important role in boosting the annual rice production in Bangladesh since independence in 1971, Aus and Aman were the major dominant crops till 1997-98. Among the three types of rice Aus, Aman and Boro; the Boro rice alone has contributed the highest share of total rice production since 1998-99 and currently accounts for more than 55% of rice produced in the country.

As shown in Figure 2.5, it revealed that both Boro rice has increased phenomenally in the last decades due to good efforts and farming facilities. During this period, Boro rice production increased almost 10 times and area increased 5 times. An analysis of production and area from the post-independence period to the end of the last century showed that both area and production of Boro rice has widely/ substantially increased. In this period, Boro production increased more than 5 times than 1972. At the end of the first decade of the current century, Boro rice production increased by 65% over the previous decade and contributed 52% to the total food grain production

(rice and wheat). In that time, production of Boro rice is 18.06 million MT in 2010 and the area of the Boro rice slightly varies from year to year within the range of 3.77 to 4.71 million ha as shown in Figure 2.5. Production of Boro rice increased to 18.78 million MT in 2011-2012 from the production of 18.62 million MT in 2010-2011. Since then the production has been increasing gradually each year and hit 20.388 million MT in 2018-19, that is all time high since the independence but declined in 2017-18. But in that time, there was almost no growth. It seems the area of Boro has reached its pick.

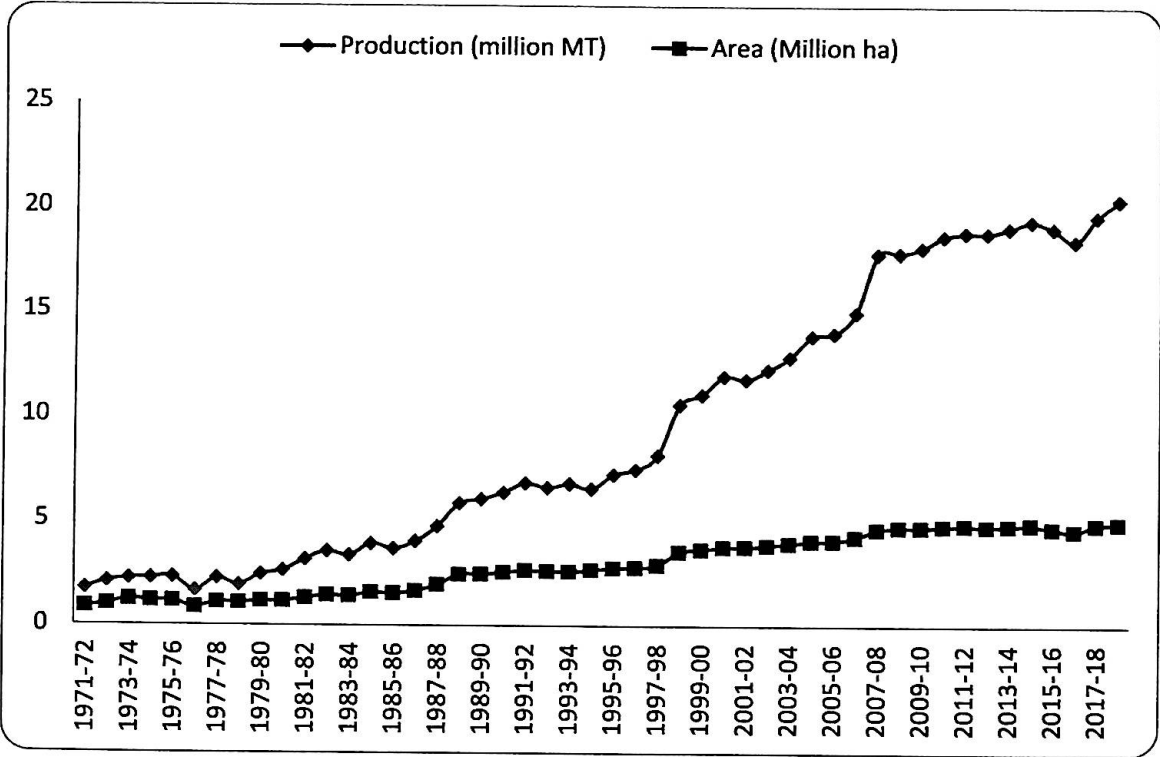


Figure 2.5: Area and production trend of Boro rice in Bangladesh

(Source: Bangladesh Bureau of Statistics, BBS)

CHAPTER III

REVIEW OF LITERATURE

REVIEW OF LITERATURE

3.1. Introduction

The review of literature is an important part and justifying the dissertation on which the total focuses depends as will need to explain the relevance of the literatures that have pertained. In this chapter, how the reviewed literatures support the proposed problem and examination the similarities with overall impact on the topic findings have investigated. As such, an overview of the theoretical views and empirical finding of the past and present investigations, theoretical review for the measurement of technical efficiency and the empirical review with corresponding measures of technical efficiency are included. Further Stochastic Frontier Approaches, Global Review of Efficiency Studies on Agriculture, Technical Efficiency Determinants, Global Review of Efficiency on Rice Farming, Review of Empirical Studies in Asia and Bangladesh have discussed accordingly.

3.2. Review of theoretical approaches

As we are intended to investigate the problem- how the farmers of the study area is technically efficient in the aspect of the Boro production, the concepts Technical Efficiency, Measuring Technical Efficiency, Input Oriented Measures of TE, Output Oriented Measures of TE are important and the literatures are reviewed herewith.

3.2.1. Review efficiency on conceptual aspects

Efficiency is the most important technique used in econometrics and its related areas. The efficiency introduced by the revolutionary work of Debreu (1951) and Koopmans (1951) and nowadays it is the most widely used concepts in Econometrics. The efficiency is defined as the measure of the firm's success in producing maximum output from a given set of inputs (Farrell (1957) and it is characterized as technical efficiency. In general, efficiency is a quantitatively

determined by the ratio of useful output to total input and mathematically expressed as $r = \frac{P}{C}$, where P is the amount of useful output (product) produced per the amount C (cost) of resources consumed (Wikipedia). Lin *et al.*, (2011) argue that efficiency is a concept that originates from physics or engineering and refers to the optimization of resource allocation to maximize output levels, using minimum resource costs in order to achieve stated business operational goals. According to Arene, (2008), it is the relative performance of the different processes used in transforming given input into outputs. Good performance in production theory can be achieved in an abundance of theoretical and empirical research. To meet objectives of data based research, the degree of success may be also achieved by allocating inputs as the representative for the outputs as an effort of the researcher (Kumbhakar and Lovell, 2000 and Charnes *et al.*, 1978). Cooper *et al.*, (2004) mentioned that efficiency is simply defined as the ratio of output to input. A comparison have made between the observed and the frontier output (Fried *et al.*, 2008). Thus, a unit or units, with fix technology and proper management may produce the maximum performance output for given inputs.

3.2.2. Review of technical efficiency

Technical efficiency is the efficacy for the output of producers or farmers with a given set of inputs and it refers to the ability to avoid wastage by either producing as much output as technology or input usage allowed. A technically efficient firm produces the maximum output using minimum quantity of inputs and technology. In the same way, Ellis (1988) defines technical efficiency as the maximum possible level of output attainable from a given set of inputs, given a range of alternative technologies available. Technical efficiency is defined as the ability to minimize input usage in the production of a given output vector or the ability to obtain maximum output from the given input vector (Kumbhakar and Lovell, 2000). The maximum level of output for a given inputs may attain by given range of alternative technologies of the farmers (Kebede 2001). Technical efficiency means producing maximum output with given inputs; or equivalently, using minimum inputs to

produce a given output (Yang, 2005). Likewise, according to (Coelli *et al.*, 2005) technical efficiency is the level to which the maximum possible output is achieved from a given combination of available inputs. As therefore, the TE can be regarded as the measurement that inputs are transformed into outputs, or just the output/input ratio (Qiu and Chen, 2006). The concept of TE can be better to explain graphically using a simple example for a producer using two factors X_1 and X_2 of firms to generate a single output (Y).

3.2.3. Approaches of determining TE

Both input and output oriented TE are using in the literatures and sequential discussion are included. Technical efficiency can be measured within two main approaches in general, which are input-oriented and output-oriented. When input quantities are fixed so that output varies across producers, the efficiency measure is output-oriented because the objective of producers is to maximize output. When output quantities are fixed so that inputs vary across producers, the efficiency measure is input-oriented because the objective of producers is to best allocate input quantities and minimize input usage (Kokkinou, 2012). In an input-oriented approach, technical efficiency provides the potential input reduction that a farmer could apply without reducing its output level (Kopp, 1981). Reduction of all inputs proportion is the main concern in the input-oriented approach whereas, in an output-oriented approach, technical efficiency provides information about the potential output increase that a farmer could gain without increasing its use of inputs. How much output could be expanded from a given level of inputs is of interest in the output approach is known as output shortfall. This is the opposite of input oriented approach. Both measures will coincide when the technology exhibits constant returns to scale, but are likely to vary otherwise (Coelli *et al.*, 2005). In figure 1, the concept of TE of combinations of inputs, X_1 and X_2 , used in producing output Q are drawn as-

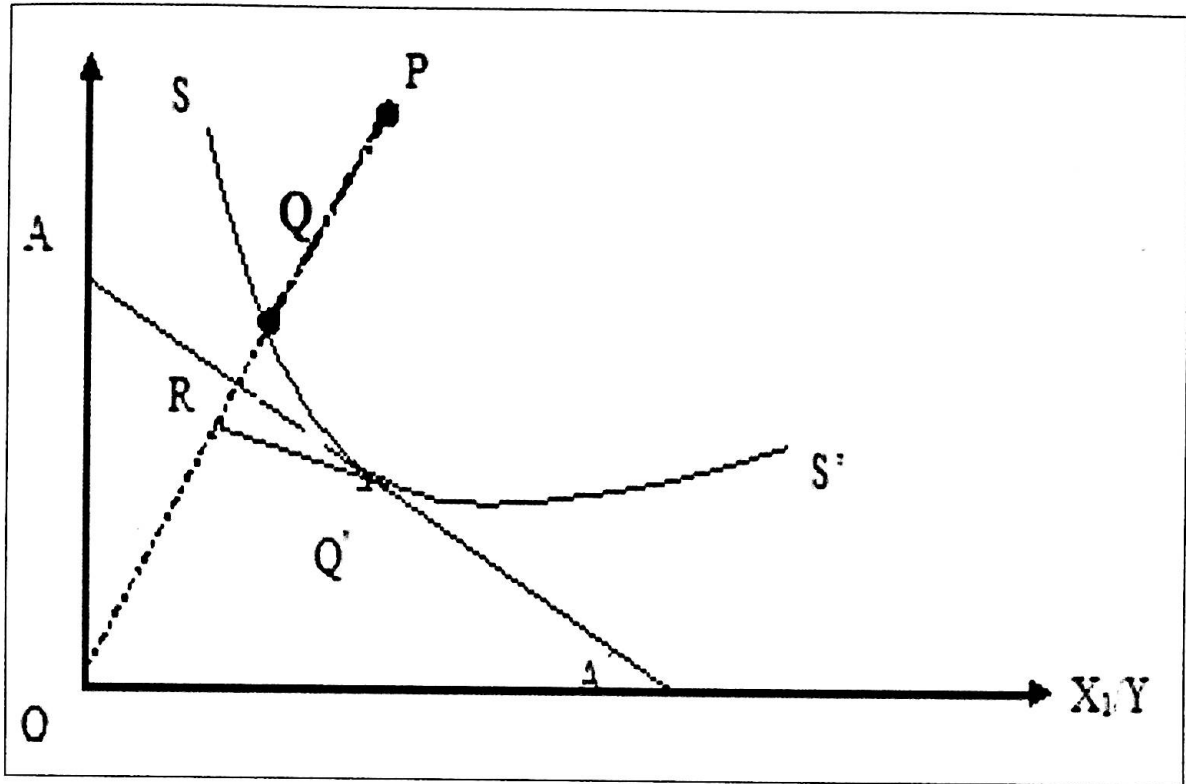


Figure 3.1: Input oriented decomposition function

(Source: Coelli *et al.*, (2005))

Where, SS' is the best practice production frontier, AA' is an iso-cost line, Q' is the maximize profits (point of tangency) and Q' the producer is economically efficient. If a farmer producing output depicted by iso-quant SS' with input combination level of (X_1 and X_2) production combination (P) is not technically efficient because of inputs levels to produce the same quantity is Q on iso-quant SS' . The degree of TE measured by OQ/OP is proportional in all inputs that could theoretically be achieved. Hence, all farmers that produce along in the iso-quant are cent efficient. The technical efficiency is most commonly measured by the ratio: $TE = OQ/OP$ which is equivalent to $1 - QP/OP$.

Considering the input quantity constant at a particular level, the technology can be represented by a two dimensional curve of output oriented figure for (Y_1 and Y_2) and a single input (L) is as-

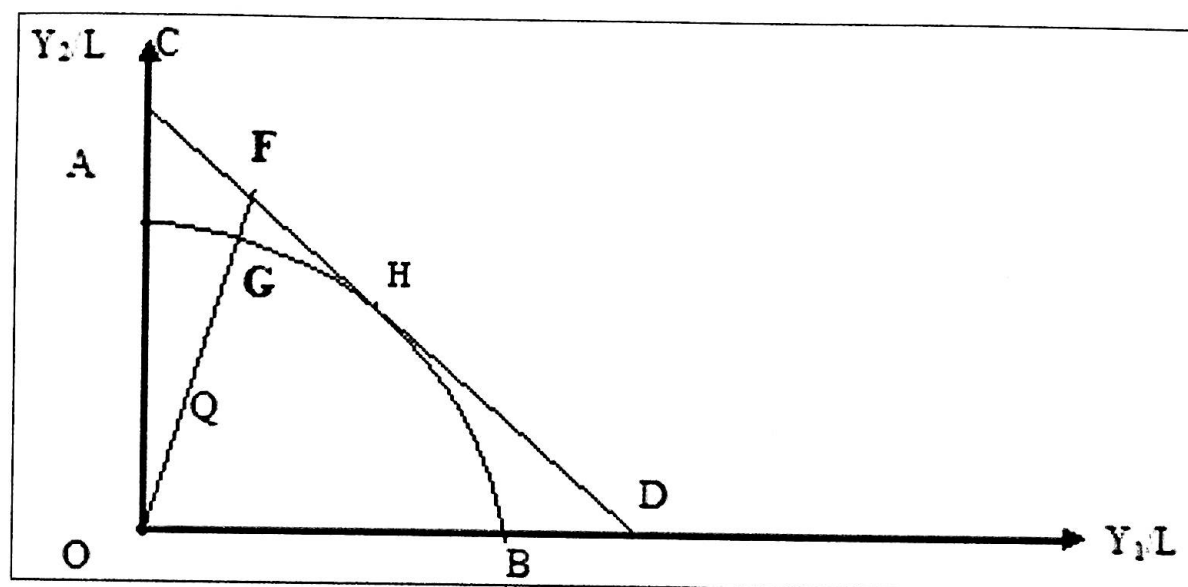


Figure 3.2: Output-oriented illustration of technical efficiency

(Source: Coelli *et al.*, 2005)

The production possibility curve is represented by the curve AB in Figure 3.2, which represents technically efficient combinations of production of outputs Y_1/L and Y_2/L . The economically efficient point is H where the marginal rate of product transformation equals the slope of the iso-revenue line CD. Consider a firm situated at point Q. The TE is represented by $\frac{OQ}{OG}$ means that all farmers producing along 100% of the TE.

3.2.3.1. Data envelopment analysis (DEA)

The DEA is a non-parametric measurement technique mainly based on mathematical programming to measure the efficiency level without imposing any functional form/assumptions of inefficiency. A number of researchers Debreu (1951), Koopmans (1951) Farrell (1957) and Charnes *et al.*, (1978) established DEA but extended part have developed by Banker *et al.*, (1984). Technical efficiency estimation using DEA involves the use of a linear programming method to construct a non-parametric frontier over the sample data. Efficiency is estimated using the

distances of each observation relative to the frontier (Coelli *et al.*, 2005). Furthermore, efficiency estimation using DEA is sensitive to outlying observations and misleading information (Sarafidis, 2002 and Fried *et al.*, 2008). There is an alternative technique of efficiency measurement called SFA.

3.2.3.2. Stochastic frontier approach

Stochastic frontier analysis (SFA) is the dominant parametric method, which conceptualizes the production process through an additive mathematical operation of a monotonous and concave function, efficiency or inefficiency component, and an error term that captures the statistical noise or measurement errors (Coelli *et al.*, 2005). Development of SFA was the theoretical literature on productive efficiency which began in the 1950s with the work of Koopmans (1951), Debreu (1951), Shephard (1953) and Farrell (1957). Aigner *et al.*, (1977) and Meeusen and van den Broeck (1977) introduced the SFA model simultaneously. The SFA model allows for technical inefficiency and a symmetric random noise error terms (Kumbhakar and Lovell, 2000). The SFA model handles the effects of inefficiency and random noise on output separately through the introduction of a composed error term. The composed error term consists of a symmetric disturbance term and a non-negative inefficiency term (Kumbhakar and Lovell, 2000). Thus, specification of the SFA model permits output to be specified as a function of controllable factors of production, random noise and technical inefficiency (Kumbhakar and Lovell, 2000).

SFA uses Maximum Likelihood Estimation (MLE) to estimate a frontier function in a given sample, which is the method first used by Greene (1980) and Stevenson (1980). MLE can estimate the production function parameters and the technical inefficiency model parameters, simultaneously (Porcelli, 2009). The MLE of an unknown parameter is used to produce efficiency estimation and SFA follows various assumptions about the distributions of the random noise and inefficiency variables that potentially lead to more reliable efficiency estimations (Kumbhakar

and Lovell, 2000). The symmetric disturbance term is assumed to be identically, independently and normally distributed with zero mean and constant variance. The inefficiency variable, however, has developed into different distributional assumptions. In the original development of SFA, Half-Normal and Exponential distribution were considered (Aigner *et al.*, 1977). These assumptions were developed into more flexible general distributions such as Gamma-distribution (Greene, 1980), Truncated-Normal distribution (Stevenson, 1980) and the four-parameter Pearson family distributions (Lee, 1983). The half-normal and exponential distributions assume mode at zero, implying the highest proportion of the producers examined are perfectly efficient. Truncated-Normal and Gamma distributions however, allow wider ranges of distributional shapes including non-zero means. The truncated Normal distribution assumes one-sided error that is obtained by truncating at zero with the possibility of a non-zero mean that also generalizes the Half-Normal distribution (Fried *et al.*, 2008). The main strength of the SFA is that the effects of random noise on output can be separated from the effects of technical inefficiency (Fried *et al.*, 2008). When random influences and statistical noises are perceived to influence the data and when the omitted variables may influence the final results, SFA is preferred. Moreover, when hypothesis testing is important and measurement of goodness of fit of the estimated model is required, SFA model is more appropriate (Sarafidis, 2002). The various regression method like, OLS, Tobit, Logit and Probit regression models (Chepng'etich *et al.*, 2015) were used before SFA development.

3.3. Review of empirical studies on efficiency

Worldwide a great deal of empirical studies have been conducted to measure the technical efficiency of rice farmers and identified different factors which are associated with production and technical inefficiency level by using production function, mathematical programming technique, panel data, as well as using the cross-section data. This section includes the detailed literature review of determining the technical efficiency and its determinants emphasizing rice production in Bangladesh and the world.

To assess the TE and factors affecting the production of maize farming at Bone Kacintala subdistrict, Muna district, Southeast Sulawesi Geo (2020) conducted using a CD production function and Stochastic Frontier. The Land, seed and fertilizer have found to be significant effect on maize production. Hailu (2020) conducted a study to estimate level of technical efficiency and identify factors affecting technical efficiency of wheat producing farmers in Ethiopia. The results showed that the plot size, labor, seed, fertilizer and chemicals were the major factors that influence changes in wheat output and average technical efficiency of wheat producers is 62%. The distant of wheat plot have identified as negative but significant effect on technical efficiency level of the farmers. Widi and Isyanto (2020) applied SFA model for sweet potato production in Kuningan district of West Java Province, Indonesia. Abate *et al.*, (2019) estimated the TE as well as the factors that constitutes the determinants of the TE of smallholder red pepper farmers in North Gondar of Ethiopia. The results indicated the technical efficiency scores of red pepper was ranged from 16% to 94.9% with a mean 78.80%. The estimated Stochastic Production Frontier (SPF) model indicated that land, seed, chemical, oxen and labor are significant determinants of the red pepper production level. The estimated SPF model together with the inefficiency parameters also showed that age, education status, land size, land fragmentation, extension service, credit access and market information were found to statistically and significantly impact on technical inefficiency of the red pepper producers in the study area. TE and its determinants of maize production in eastern Terai of Nepal were examined by Adhikari *et al.*, (2018). The fertilizer effect of urea, DAP and the area have positive significant impact on the production, where negative impact of seed quantity have found with the mean technical efficiency as 0.79. Lamichhane *et al.*, (2019) fitted a model and determined the parameters in potato production using SPF in Nepal. The MLE of the parameter revealed that, the mean technical efficiency was 79%. The coefficient for the parameter seed, urea, DAP, MOP and labour were positive contributing for the

production of potato while, the parameter compost, pesticides, herbicides and hour of tractor use were negative but insignificant implying that these inputs are possibly being over utilized. The results further indicated strong evidence that farm size, level of education, extension contact are important factors for improving the technical efficiency level for potato production in the study area.

A study conducted in the four main agro ecological zones of Ghana by Abawiera and Dadson (2016) on technical efficiency among the maize producers. The study found that mean technical efficiency of selected farmers was 58.1% and SFP function analysis for maize farmers revealed that fertilizer, herbicides, pesticides and land inputs had positive effects on the output of maize whereas labour input had a negative sign. The study also revealed that positive impacts of educational level, farming experience, extension contact as well as uses of fertilizer and improved seeds on technical efficiency of maize producers in Ghana. Factors affecting technical efficiency among smallholder Bean farmers in Rwanda were analysed by Narcisse *et al.*, (2019) using a random sample of 276 bean farmers. They recorded the mean technical efficiency for bean producers as 0.23. The age, educational level, fertilizers, labor, land size, seeds, extension contact and access to credit were significant sources of technical inefficiency. Conversely, family size, type of seeds, and experience, had no significant impact on farmers' efficiency.

Velasco (2019) used Stochastic Frontier Approach (SFA) to assess the management practices and technical efficiency of the Magsasaka at Siyentipiko para sa Pag-unlad ng Agrikultura (MASIPAG) rice farmers in Isabela, Philippines using primary data of 64 respondents. The results indicated that seeds, fertilizer, pre and post-harvest labor and capital were found to be significant indicators of technical efficiency. The technical inefficiency model also showed that age, farming system, household size, educational attainment, number of years in farming, type of soil, crop establishment were found to be significant indicators of technical in efficiency for the MASIPAG

farmers. Using stochastic production frontier and inefficiency models Sayavong (2018) examine rice production in Laos and identified the troubling factors of efficiency. Based on cross-sectional data of key inputs such as farmland, labour, capital, water supply and other expenses were analyzed in the production model. Similarly, the impact of specific factors like farmers' education, soil quality, credit access, extension services, and environmental conditions were examined in the inefficiency model. The findings indicated that the potential of 77.75% of Laos' paddy rice output has been realized and that knowledge transfer among farmers

Meenasulochani *et al.*, (2018) made to assess the technical efficiency of paddy production and factors affecting the efficiency to paddy production in Nagapattinam district of Tamil Nadu using a stochastic frontier production function and tobit model. Result found that the mean technical efficiency was 80.42% and the coefficients of variables such as organic fertilizer, plant protection chemical, labours and machinery usage are negative which reveals that the volume of output varies inversely to the quantity of these variables while farm size, seed, chemical fertilizer and irrigation are positive, which reveals that the volume of output varies proportionately to the quantity of these variables.

Istiyanti *et al.*, (2018) did a study to analyze the technical efficiency and the factors that affect the technical inefficiency of organic rice farming in Bantul Regency Special Region of Yogyakarta, Indonesia using frontier production function. They showed that the average level of technical efficiency of organic rice farming in Bantul Regency is 0.71. The area of land, seed and manure has significant impact on the production of organic rice with positive coefficient, whereas organic fertilizer has significant impact with the negative coefficient. The impact of farmers' educational level was marked as significant on technical inefficiency model in the organic rice farming. Alternatively, farmers' age, farming experience and the land status do not significantly affect the technical inefficiency.

Kerdsriserm *et al.*, (2018) analyzed and compared the technical efficiency of three different rice farming production systems namely, organic rice farming under the Alternative Agriculture Network (AAN), conventional organic rice farming and chemical rice farming in eastern Thailand applying a stochastic frontier analysis. Farm-level data were collected during the 2016-2017 production period from 150 respondents consisting of 58 organic farmers under the AAN, 42 conventional organic rice farmers and 50 chemical rice farmers from Chachoengsao and Prachinburi provinces, major rice producers in eastern Thailand. The results revealed that the technical efficiency scores for organic rice farmers under the AAN model. The average TE under ANN were found 0.733 whereas it was 0.669 by traditional model for the organic rice farmers and it was approximately 0.688 chemical rice farmers. Although the farm size had a positive and significant impact all other variables considered in model are insignificant on productivity of rice in the study areas. In tank-irrigated systems of the southern zone in Tamil Nadu, India, Vasanthi *et al.*, conducted a study in 2017 using Stochastic Frontier Production approach. They estimated technical efficiency of paddy production for two years 2009-10 and 2010-11 and the estimated efficiency of the farmers for the years 2009-10 were found in between 54% to 98% with a mean of 85%, but for the years 2009-10 technical efficiency of the farmers have found in between 52% to 98% with a mean of 87%. On the other hand, technical efficiency of the farmers for the years jointly have found to the interval 52% to 98% with a mean of 87%. The results of stochastic production function indicated that the input variables seed, fertilizer nutrients, labour hours, Machine hours and pesticide are significant. Age and farm size were found to be the significant determinants which affect the efficiency levels of rice production in the study area.

Shaheen *et al.*, (2017) estimated the technical efficiency of conventional and dry rice farmers and determine the factors which contribute to increase the rice output in rice growing areas of Punjab, Pakistan applying SFA. Study results revealed that average

technical efficiency of sample rice farmers is 86 percent, ranges from 0.34 to 0.97. Area, NPK, Seed, number of irrigation hour, weedicides and pesticide variables would significantly contribute to improve the rice production. Moreover, the study results indicated that education, experience, owner status, tenant, distance from main market, credit access, tractor, tube-well, extension contact and family size were the significant determinants of the technical efficiency. A study was conducted by Kea *et al.*, in 2016 for Cambodian household's rice production considering its main influencing factors under SFA model using primary data of 301 rice farmers in three selected districts of Battambang by structured questionnaires. The empirical results showed that famers produce 34% of rice at best practice at the current level of production inputs and technology. It revealed that rice output has the potential of being increased further by 66% at the same level of inputs variables land, fertilizer and pesticide if farmers had been technically efficient. Surendra (2016) performed a study to measure the technical efficiency of rice farms of the north-eastern region of Thailand and pointed out the factors affecting technical efficiency of rice growers as regard of environmental factors using a survey data of the International Rice Research Institute (IRRI), collected in 2012 from the Nakhon Ratchasima province of Thailand. To analyze the data stochastic frontier production method in Cobb-Douglas functional form was applied. The results shows that, mean technical efficiency score of rice farmers in that area is about 0.41 and the coefficient of land, labour and capital were found to positively influence rice productivity while that of seed negatively influenced rice productivity. Age and drought condition were found to be the significant determinants which affect the efficiency levels of rice growers in the study area. Prasanna and Lakmali (2016) used the SPF Model to identify the determinants of technical inefficiency among smallholder potato producers in of with the help of a random sample of 100 potato farmers. The MLE technique was used by Welimada in Sri Lanka and the results revealed that the mean TE of potato production was 72% for smallholder potato farmers. The irrigation cost, seed cost,

fertilizer cost and pesticides cost were positive and statistically significant production factors. The also showed that age, education, household size, farming experience, irrigated area, and land ownership were statistically significant inefficiency factors.

3.3.1. Empirical review of TE in Bangladesh

Sometimes farmers fail to exploit the complete potentials of technology as well as to make the allocative errors in developing countries (see Gelan and Muriithi, 2012 and Rao, 2012). As such, increasing efficiency in production function assumes greater significance in attaining potential output. Recently, a limited number of empirical researches have strived to analyze factors influencing the agricultural production efficiency in Bangladesh. Those studies showed the presence of technical (in)efficiencies in almost all over the country. Among those studies, “Hasan *et al.*, (2020), Akter *et al.*, (2020), Hoque *et al.*, (2019), Mitra and Yunus (2018), Hossain-Majumder, 2018, Sarker *et al.*, (2017), Anik *et al.*, (2017), Uddin other (2017), Hossain (2016), Sarker and Alam (2016), Hossain *et al.*, (2015), Ali and Samad (2013), Rahman *et al.*, (2013a). Baree (2012), Islam *et al.*, (2012), Hasan and Islam (2010), Ali and Samad (2010) performed SFA analysis of various crop farmers in different regions and assumptions with the help of some variables. They identify the sources of technical efficiency/inefficiency. Studies on technical efficiency of rice production in Bangladesh are somehow limited. A detailed review of the relevant studies is given below.

A research on the Boro rice production by Hasan *et al.*, in 2016 has performed in Jhenaidah district of Bangladesh using SFA model. The study identified about 92% of the TE and also found affecting factors including the cost of labor, irrigation, seed etc. Further, they showed some inefficiency variables related for Boro rice production. Hasnain *et al.*, (2015) analyzed the TE of Boro rice farm in Meherpur district, Bangladesh using the translog stochastic frontier production function. More than 89% technical efficiency of Boro rice farms was computed.

Roy and Hamid (2014) studied on technical efficiency of hybrid rice production and its determinants following stochastic production frontier of the farmers in Dighalia Upazila of Khulna District, Bangladesh using cross-sectional primary data. Both OLS and MLE estimator have computed. The labor, fertilizer, and herbicide have positive and significant influence on rice production but land and seed show significant negative relation with output by OLS. However, the ML estimates indicated that land, labor, seed, and fertilizer are positively and significantly related with rice production. The finding also indicated that average technical efficiency in rice production was 75 percent with ranged from 28 percent to 97 percent. The socioeconomic variables like age, gender, family size, education, farm size, farming experience, land fragmentation, and formal training were used identifying statistical insignificant behaviour.

Rahman *et al.*, (2012) conducted a study to estimate the farm-size-specific productivity and technical efficiency of all rice crops using stochastic production frontiers in the cropping year 2008-2009. The results showed that the average technical efficiency for large, medium, small, marginal and all farms were respectively 0.88, 0.92, 0.94, 0.75 and 0.88. Area, fertilizer, manure, irrigation cost, insecticide cost, under production and experience were important factors to increase production. In the technical inefficiency effect, education, age and family size had positive impact on efficiency, while land under household had negative impact.

CHAPTER IV

DATA AND METHODOLOGY

DATA AND METHODOLOGY

4.1. Introduction

Research methodology with study area, data collection method and sources are discussed in this chapter. This study based on the primary data, designing of questionnaire and definitions of variables are very important. Therefore, different hypothesis, tools and techniques of data analysis have imparted with necessary discussion herewith.

4.2. Description of the study area

The northern region of Bangladesh is known as basket of rice, which is contributing the largest share in the domestic food grain production due to the largest cropping area that is vital to achieving food security of the country. The northern region alone comprises about 35 percent of the irrigated Boro rice in the whole country (BBS, 2020). The map of the northern region of Bangladesh is shown in Figure 4.1 and Figure 4.2 showing read lined boundary. Geographically, this region extends from 23°48' to 25°16' north latitudes and from 88°50' to 89°53' east longitudes covering approximately 34,494 sq km. It is surrounded by the West Bengal of India, Rajbari and Kushtia districts to the south, Assam state of India, Jamalpur, Tangail and Manikganj districts to the east and West Bengal of India. The northern region is consisting of 16 districts of Rajshahi and Rangpur divisions – is a relatively dry in the country, which is our study area. The population for the study comprises all Boro rice producers in 2018/2019 production season in the study areas.



Figure 4.1: Map of Bangladesh showing study area

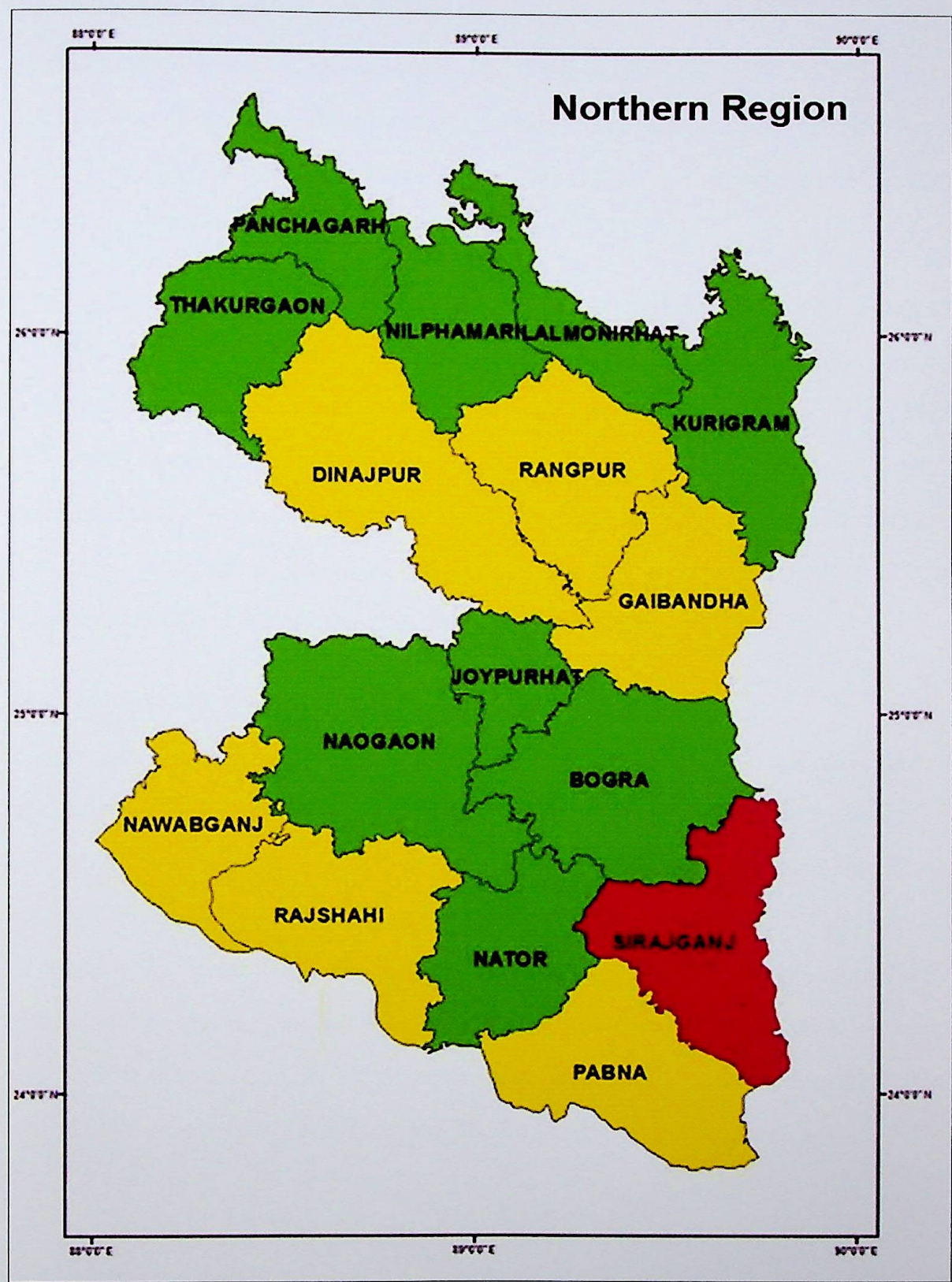


Figure 4.2: Map of Northern region

4.3. Research design

As this study is based on cross-sectional data to measure the technical efficiency of rice farmers of the study area research, it is very important give concentration on the research design. Four districts have been considered for collecting samples from the population to answer research questions of interest.

A cross-sectional study is one that produces a ‘snapshot’ of a population at a particular point in time. Either the single ‘snapshot’ of the cross sectional study provides researchers with data for a retrospective or a prospective enquiry (Cohen *et al.*, 2007). This research design is appropriate as it makes inference about the effect of one or more explanatory variables on the dependent variable by measurement unit on a number of variables at the same point in time (Gay, 1992). The sample size and sampling techniques are discussed in the next proposition.

4.3.1. Sample size determination

Sample size, a significant tool while dealing with primary data and especially since we have been using the population is homogenous in agro-ecology and production system probability proportionate to size sampling (pps) methodology (Anderson *et al.*, 2007 and Kothari, 2004). As such, determination of proper sample size is a supportive step of research for getting efficiency. The formula of estimating sample size have as widely used in the literatures (Mwangi *et al.*, 2020; Huong and Anh, 2019; Wassihun *et al.*, 2019; Abate *et al.*, 2019; Suleiman and Sule, 2019; Ayele *et al.*, 2019; Haile *et al.*, 2018; Ali and Jan, 2017; Hossain, 2016 and Ali *et al.*, 2014) are as-

$$n = \frac{z^2 pq}{e^2}(4.1),$$

where n is the required sample size,

z is the confidence level at 95% (standard value of 1.96),

p is the proportion of the population engaged in Boro rice production activities which is at 0.65. This was an assumption that 65% of farmer engages in Boro rice production in the study area,

q is the proportion of the population who do not engage in Boro rice production activities given by $1 - p$ and e is the level of precision, i.e. the acceptable margin of error for proportion being estimated that 0.05 (error researcher is willing to accept).

Assuming CI as 0.95 and margin of error as 0.05, the sample size has determined as-

$$n = \frac{z^2 pq}{e^2} = \frac{1.96^2 \times 0.65 \times 0.35}{0.05^2} = 349.59$$

Therefore, a total of 350 farmers are required as sample size in this research.

4.3.2. Sampling unit selection criterion

Using pps sampling Natore and Bogura districts from Rajshahi division and Rangpur and Dinajpur districts from Rangpur division have chosen in this study (see Figure 4.1 and Figure 4.2). According to the BBS information of production (Table 4.1) district-wise average high productivity of the years for 2016/2017 and 2017/2018 have been considered as selection criterion Boro rice farmers. Thereafter two Upazilas are selected randomly from each district and finally eight Upazilas have been selected for the study from four districts of the region. The selected Upazilas were Sonatala and Kahaloo Upazilas of Bogura district, Singra and Baraigram Upazilas of Natore district, Mithapukur and Kaunia of Rangpur and Biral and

Hakimur Upazilas of Dinajpur district. In the next stage from each Upazilas two villages were selected randomly based on the availability of a representative sample for the study. The sampling diagram is shown in Figure 4.3.

Table 4.1: District-wise average of two years Boro rice production.

District	2016-17			2017-18		
Rajshahi Division						
	Area (ha)	Production (MT)	Yield (MT/ha)	Area (ha)	Production (MT)	Yield (MT/ha)
Bogura	185741	719981	3.876	187013	728268	3.894
Joypurhat	68027	293753	4.318	68035	277035	4.072
Naogaon	192009	789518	4.112	199007	813546	4.088
Natore	52613	242318	4.606	59225	274525	4.635
Nawabgonj	46141	175669	3.807	47079	183143	3.890
Pabna	60554	241412	3.987	56317	225208	3.999
Rajshahi	66717	272701	4.087	69175	269551	3.897
Sirajgonj	137923	566275	4.106	139338	588606	4.224
Rangpur Division						
	Area (ha)	Production (MT)	Yield (MT/ha)	Area (ha)	Production (MT)	Yield (MT/ha)
Dinajpur	176509	707246	4.007	175290	716477	4.087
Gaibandha	125368	481241	3.839	125099	458840	3.668
Kurigram	107030	428420	4.003	117321	485934	4.142
Lalmonirhat	47875	197277	4.121	47851	178761	3.736
Nilphamari	80408	338249	4.207	101166	411224	4.065
Panchagar	36024	147361	4.091	35308	144219	4.085
Rangpur	132796	565685	4.260	141693	616865	4.354
Thakurgaon	59964	253090	4.221	67529	252528	3.740

(Source: Yearbook of Agricultural Statistics-2018)

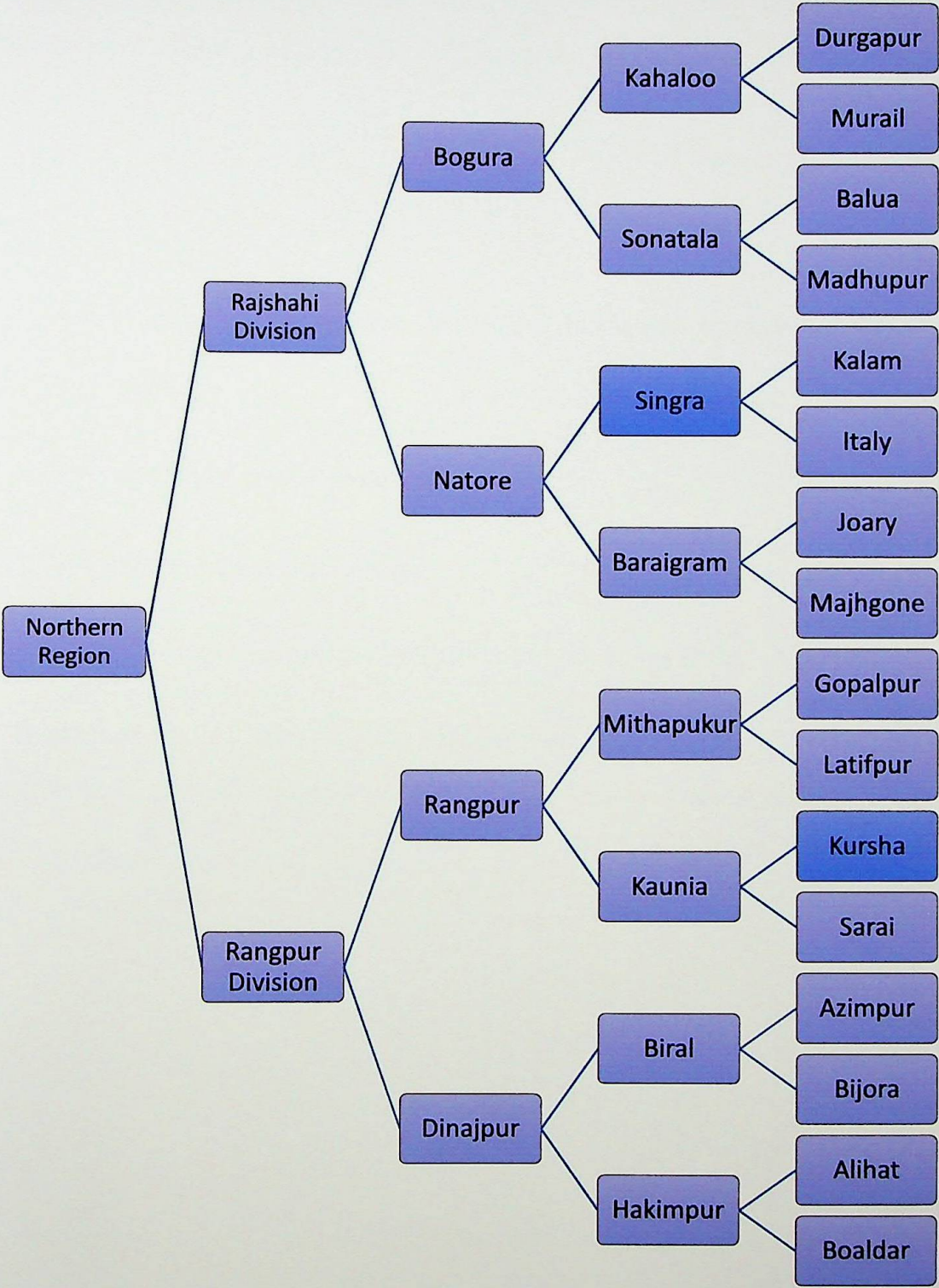


Figure 4.3: Sampling diagram of the research design.

To collect sample farmers up-to-date list of Boro producers of different villages have used from the respective agriculture office of Upazilas. In the final stage 350 Boro producers have selected with the help of Cochran’s formula developed in 1977 as-

$$n_i = \frac{N_i \times n}{N} \dots\dots\dots (4.2),$$

where,

n_i = Number of Boro rice producers randomly interviewed in selected villages;

N_i = Number of total Boro rice producers;

n = Sample size for the study;

N = Total number of Boro rice growers in the study area.

The final units in this study for the villages and sample sizes are summarized for respectively for the selected districts and presented in the Table 4.2.

Table 4.2: Selected sampling unit and number of individuals.

Districts	Upazila	Village	No. farmers <i>N_i</i>	Cumulative Sum	Probability (%)	Sample Size (<i>n_i</i>)
Natore (88)	Singra (48)	Kalam	341	341	7	25
		Italy	311	652	7	23
	Baraigram (40)	Joari	297	949	6	22
		Majhgone	243	1192	5	18
Bogura (98)	Sonatala (51)	Balua	324	1516	7	24
		Madhupur	365	1881	8	27
	Kahaloo (47)	Durgapur	284	2165	6	21
		Murail	351	2516	7	26
Rangpur (84)	Mithapukur (40)	Gopalpur	203	2719	4	15
		Latifpur	338	3057	7	25
	Kaunia (44)	Kursha	365	3422	8	27
		Sarai	230	3652	5	17
Dinajpur (80)	Biral (42)	Azimpur	270	3922	6	20
		Bijora	297	4219	6	22
	Hakimpur (38)	Alihat	230	4449	5	17
		Boaldar	284	4733	6	21
Total	350		<i>N</i> = 4733		100	<i>n</i> =350

(Sources: Upazila Agriculture Offices)

4.4. Designing of questionnaire and data collection

The sampled farmers were interviewed personally either at their farms or at residence. The primary data were collected among the Boro rice farmers in the study area by the researcher with the help of two trained enumerators from statistics discipline. Data on socioeconomic, demographic, institutional and farm specific variables such as age, household size, education level, access to credit and extension facilities as well as the output quantities and inputs used in Boro rice production were gathered from the respondents by face to face interview with the help of well-structured questionnaire designed for the study in January to April 2018.

A well-prepared and pretested questionnaire (Appendix I) with both close ended and open-ended questions would be primed for collection of primary data from the Boro rice farmers during the cropping period January to May, 2018. The questionnaire was designed on the basis of knowledge of some similar previous questionnaires. It was aimed to make the questionnaire a structured, target oriented and at the same time flexible enough to accommodate the general impression of the respondent about the overall effect of intensive cropping on natural resources in the study areas. The questionnaire was checked by the expert panel and corrected according to their comments. The questionnaire was pre-tested during the early field visits before being finalized. Few corrections and modifications were identified during presentation. The questionnaire comprised four sections. The first section consisted of identification of the farmers as well as the district and operational area of the farmers. The second section included questions on Boro rice producers' socio-economic and demographic characteristics. The third section dealt with questions on inputs or resources employed in production process including output of Boro rice while the fourth section posed questions on the output of Boro rice and its farming activities.

4.4.1 Secondary information .

Some secondary information which are relevant to the research were collected from various published sources such as textbooks, journals, research reports and periodicals with due reference and acknowledge. Besides these some more information from the sources of FAOSTAT, Department of Agriculture Extension (DAE), Bangladesh Rice Research Institute (BRRI) and Bangladesh Bureau of Statistics (BBS) have used according to the necessity.

4.4.2. Variable uses in the study

The following input variables are enlisted and have been used in the estimation of production functions as explanatory variables that can affect the output.

Land (Land)

Land was a continuous variable measured as the total crop area in bigha under the management of the sample farmer including own, rented-in, and cultivated through sharecropping arrangement. It is the vital facility in food production. According to some empirical studies the variable land could have either positive or negative impact on productivity (Narcisse *et al.*, 2019; Rukwe and Zubairu, 2019; Dessale *et al.*, 2018; Ahmadzai, 2017; Oluwatusin *et al.*, 2017; Tabe-Ojong and Molua, 2017; Dube *et al.*, 2018; Dessale, 2018 and Alemu *et al.*, 2018).

Human labour cost (Labor)

Human labour cost was one of the most important and largest cost items in the production process of Boro rice and it is largely used input in producing Boro rice. Human Labour is required for various activities and management, such as, land preparation, transplanting, weeding, fertilizing, using insecticides and herbicides, harvesting, threshing, cleaning, drying and winnowing. Empirical evidence provided

by various studies that it was expected that labour would have a positive influence on output (Wollie, 2018; Wana and Sori, 2018; Dube *et al.*, 2018; Dessale, 2018; Alemu *et al.*, 2018; Sani and Oladimeji, 2017; Ahmadzai, 2017), Bapari *et al.*, 2016).

Fertilizers cost (Fert)

Fertilizer is a key input and its application along with other technologies will have a great potential to increase crop productivity. Consequently, fertilizer is the most important nutrient factor in soils and plays the most vital role in Boro rice production in Bangladesh. So, optimum dose of fertilizer is a major requirement for Boro rice production. In the study area, the sample farmers used mostly different kind of inorganic fertilizers, namely, Urea, Triple Super Phosphate (TSP), Muriate of Potash (MOP), Gypsum and Boron in producing Boro rice, though few of them used also organic fertilizers, namely, compost, cow dung, oilcake, etc. It was expected that fertilizer will have a positive effect on yield. Empirical evidences (Wollie, 2018; Adhikari *et al.*, 2018; Dessale, 2018; Alemu *et al.*, 2018; Oluwatusin *et al.*, 2017; Tabe-Ojong and Molua, 2017; Sani and Oladimeji, 2017; Ahmadzai, 2017; Prasanna and Lakmali, 2016; Bapari *et al.*, 2016; Hossain, 2016; Alwarritzia Hossain *et al.*, 2015; Nkang and Ele, 2014) indicate that fertilizer positively and significantly influences on agricultural productivity across the world.

Seed cost (Seed)

Seed is one of the principal inputs in the production processes of rice. In the study area, farmers used various types of seed from various sources of seed suppliers, namely open market, dealer, GO, NGO, etc. Only few farmers used home supplied seedlings. The cost of seed varied widely depending on its quality and availability of seed. It was expected that seed cost will have a positive effect on yield. Several

researchers such as Wana and Sori (2018); Dube *et al.*, (2018); Tabe-Ojong and Molua (2017); Ahmadzai (2017), Oluwatusin *et al.*, (2017) Sani and Oladimeji (2017); Hossain (2016); Bapari *et al.*, (2016) identified that seed the production factors with significant influence on various crops in agriculture sector.

Pesticides cost (Pest)

As agricultural pest management insecticides, fungicides, herbicides, rodenticides, molluscicides, nematocides, plant growth regulators (Aktar *et al.*, 2009) are using in the world. Benefits of pesticides include increased food production, increased profits for farmers and the prevention of diseases. The price of the insecticides largely varied from brand to brand. The insecticide cost was determined on the basis of actual price paid by the farmers and the actual cost of insecticide was used. Its influence on output could be positive or negative. Some important studies have been conducted to identifying the association between pesticide and agricultural output. (see Tariq *et al.*, 2018; Yekti *et al.*, 2015; Oseni *et al.*, 2015; Dang, 2017; Narala and Zala, 2010).

Harvesting cost (Harv)

Along with other agricultural operations harvesting plays an important role on crop production. It is the process of collecting the mature crop from the field. It is therefore important to apply good harvesting methods to be able to maximize grain yield, and minimize grain damage and quality deterioration. Harvesting of Boro rice includes cutting, stacking and handling, threshing and cleaning. So, proper timing and harvesting method of Boro rice is very important to reduce losses that affecting the total production.

Farmers of most areas faced an acute crisis of labor during Boro harvesting time. Majority of the Boro rice farmers in the study area were smallholders and they rely on manual system for harvesting. Because of they had no ability to buy reaper or combined harvester machines. However many farmers were also utilizing reaper or combined harvester machines in rented for harvesting Boro rice. Consequently, farmers generally paid higher wages during harvesting period. Thus apart from labor cost, harvesting cost was considered as an explanatory variable in production analysis.

Age (Age)

Age refers to the number of years of an individual attained from birth. It is continuous variable and measured in number of years was used as a proxy measure to indicate the general farming experience, of the sample farmer. It was also considered as a inefficiency variable which may be the reflection of adopting or rejecting a new technique or practice could be determined the management experience of the farmer. Consequently, it was hypothesized that the variable Age could have either positive or negative impact on technical efficiency (Narcisse *et al.*, 2019; Rukwe and Zubairu, 2019; Lamichhane *et al.*, 2019; Dessale *et al.*, 2018; Tefaye and Beshir, 2014; Etwire *et al.*, 2013; Nwaru, 2004; Ajibefun and Aderinola, 2003). It is the experice in every sense and the the farmers who have aged are supposed to gather more experience. Hence, they are more efficient than that of Youngers. However, to new ideas and techniques older farmers are less likely to adopt innovations and thus would be less technically efficient than younger farmers. This was due to the young farmers performed better in agricultural works and they were more interested in adopting new technologies than the older farmers.

Farming experience (Fexp)

Farming experience is continuous variable and measured as the number of years that farmers have been into rice production. Farmers with many years of rice farming experience will more likely be familiar with the required skills needed for rice production and therefore are more likely to have higher outputs and consequently more technically efficient. Rice farming experience is therefore expected to have a positive effect on the output and efficiency of rice farmers in the study area. Unexpectedly, studies of Kibret and Abebo (2019), Usman (2017), Zalkuw *et al.*, (2014) and Adeoye *et al.*, (2011) confirmed the negative impact of farming experience on technical efficiency.

Unexpectedly, studies of “Kibret and Abebo (2019) and Usman (2017) confirmed the negative impact of farming experience on technical efficiency.

Family size (Fmem)

Family size refers to the number of members who are currently living within the family. The impact of family size on technical efficiency could be positive or negative. With regards to family size, some studies established a positive relationship while others established a negative relationship. Some evidential studies (Rukwe and Zubairu, 2019; Saysay *et al.*, 2018; Adhikari *et al.*, 2018; Mukhtar *et al.*, 2018; Al-hassan, 2008, Ahmed *et al.*, 2014; Adamu *et al.*, 2015; Simpa *et al.*, 2014) are supported the previous deceleration.

4.5. Data processing and analysis tools

The collected data are carefully edited to eliminate all sorts of abnormalities or personal biases. Data accuracy have been tested by the popular Cronobach’s Alpha test. The open source R program has used to analyse the data and suitable cases MS EXCEL have also used.

4.6. Stochastic frontier approach

The Stochastic Frontier Analysis (SFA) is a method of frontier estimation that assumes a given functional form for the relationship between inputs and an output (Coelli *et al.*, 2005). In this study, the CD production function uses to determine the TEs of Boro producers. Stochastic Production Frontier (SPF) is the most suitable method in efficiency analysis having a probability of being affected by factors outside control unit. This is because of the fact that this method accounts for measuring inefficiency of these factors and technical errors occurring in the measurement and the observation (Dessale, 2019).

Farrell (1957) introduced the methodology of measuring TE following the pioneer work of Debreu and Koopmans separately developed in 1951. The modification of the basic model was initially and independently proposed by Aigner *et al.*, (1977) and Meeusen and Van den Broeck (1977) for the cross-sectional data. Further, Kumbhakar *et al.*, (1991) and Battese and Coelli (1995) extended the stochastic frontier methodology by openly introducing the determinants of technical efficiency into the model. The SFA model for Cobb-Douglas production function is

$$y = f(x_i, \beta) \exp(v_i - u_i) \dots\dots\dots (4.3),$$

- where, $i = 1, 2, 3, \dots\dots\dots n$
- and y is the scalar of output for the i th producer;
- $f(x_i, \beta)$ is a suitable production function;
- x_i is a vector of input variables used by producer i ;
- β is a vector of unknown parameters to be estimated;
- $\varepsilon_i = v_i - u_i$ is the composite error term.

The term v_i is a two sided $(-\infty \leq v_i \leq \infty)$ identically and independently normally distributed random error with mean zero and unknown variance σ_v^2 , i.e. $v_i \sim iid N(0, \sigma_v^2)$ that represents the systematic error which accounts for random variation in output due to factors outside the control of the producer, measurement of errors and other statistical noise. The term u_i , is a one sided $(u_i \geq 0)$ efficiency component that captures the inefficiency of the i th farmer in production relative to the stochastic frontier (Coelli *et al.*, 2005).

The error term u_i can follow different distributions such as, Truncated-Normal, Half-Normal, Exponential, and Gamma (Stevenson, 1980; Aigner *et al.*, 1977; Green, 1990; Meeusen and van den Broeck, 1977). Due to the popular uses half-normal and truncated normal distributional assumption on the inefficiency effects have discussed herewith. The Half-Normal stochastic frontier model was first discussed by Jondrow *et al.*, (1982) and for this distribution $u_i \sim iid N^+(0, \sigma_u^2)$ and $v_i \sim iid N(0, \sigma_v^2)$, that is noise error component. The v_i and u_i are distributed independently of each other, and of the regressors. According to Jondrow *et al.*, (1982), Half-Normal distribution has mode at zero implying that high proportions of farmers being examined are technically efficient.

The density function of $u \geq 0$ is-

$$f(u) = \frac{2}{\sqrt{2\pi}\sigma_u} \exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} \text{ and } f(v) = \frac{2}{2\pi\sigma_v} \exp\left\{-\frac{v^2}{2\sigma_v^2}\right\} \dots\dots\dots(4.4)$$

Therefore, $f(u, v) = \frac{2}{2\pi\sigma_u\sigma_v} \exp\left\{-\frac{u^2}{2\sigma_u^2} - \frac{v^2}{2\sigma_v^2}\right\} \dots\dots\dots (4.5)$

The joint density functions of u and ε is

$$f(u, \varepsilon) = \frac{2}{2\pi\sigma_u\sigma_v} \exp\left\{-\frac{u^2}{2\sigma_u^2} - \frac{(\varepsilon + u)^2}{2\sigma_v^2}\right\} \dots\dots\dots (4.6)$$

The marginal density function of error is obtained by integrating $f(u, \varepsilon)$ under u as-

$$\begin{aligned} f(\varepsilon) &= \int_0^\infty f(u, \varepsilon) du \\ &= \frac{2}{\sqrt{2\pi}\sigma} \left[1 - \Phi\left(\frac{\varepsilon\lambda}{\sigma}\right)\right] \exp\left\{-\frac{\varepsilon^2}{2\sigma^2}\right\} \\ &= \frac{2}{\sigma} \cdot \phi\left(\frac{\varepsilon}{\sigma}\right) \cdot \Phi\left(-\frac{\varepsilon\lambda}{\sigma}\right), \end{aligned}$$

where,

$\sigma = \sqrt{\sigma_u^2 + \sigma_v^2}$, $\lambda = \frac{\sigma_u}{\sigma_v}$, and $\Phi[\cdot]$ and $\phi[\cdot]$ are the standard normal cumulative distribution and density functions.

The marginal density function $f(\varepsilon)$ is asymmetrically distributed, with mean and variance

$$E(\varepsilon) = -E(u) = -\sigma_u \sqrt{\frac{2}{\pi}} \text{ and } V(\varepsilon) = \left(1 - \frac{2}{\pi}\right) \sigma^2$$

The Log Likelihood function for a sample of N producers is

$$\ln L = \left(\frac{N}{2}\right) (\ln 2\pi + \ln \sigma^2) + \sum_i \left[\ln \Phi\left[-\frac{\varepsilon_i \lambda}{\sigma}\right] - \frac{1}{2} \left(\frac{\varepsilon_i}{\sigma}\right)^2 \right] \dots\dots\dots (4.7)$$

Employing the first-order conditions of the Log Likelihood maximization enables an estimation the frontier parameters. These estimates are consistent as $N \rightarrow +\infty$.

Once the parameters are estimated, the interest centres on the estimation of inefficiency, u_i . Since $E(u_i)$ is a summary measure, it is difficult to decompose the individual residuals into the two components and to estimate the technical inefficiency for individual producers. A solution to the problem is obtained from the conditional distribution of u_i given ε_i , which contains whatever information ε_i , contains concerning u_i . Jondrow *et al.*, (1982) showed that if $u_i \sim N^+(0, \sigma_u^2)$, the conditional distribution of u given ε is

$$f(u/\varepsilon) = \frac{f(u, \varepsilon)}{f(\varepsilon)}$$

$$= \frac{1}{\sqrt{2\pi}\sigma_*} \cdot \exp\left\{-\frac{(u - \mu_*)^2}{2\sigma_*^2}\right\} \Bigg/ \left[1 - \Phi\left(-\frac{\mu_*}{\sigma_*}\right)\right] \dots\dots\dots (4.8),$$

where $\mu_* = \frac{\varepsilon\sigma_u^2}{\sigma^2}$ and $\sigma_*^2 = \frac{\sigma_u^2\sigma_v^2}{\sigma^2}$. Since $f(u/\varepsilon)$ is distributed as $N^+(\mu, \sigma^2)$, the mean of this distribution can serve as a point estimator of u_i . This is given by

$$E(u_i/\varepsilon_i) = \mu_* + \sigma_* + \left[\frac{\phi(-\mu_*/\sigma_*)}{1 - \Phi(-\mu_*/\sigma_*)} \right]$$

$$= \sigma_* \left[\frac{\phi(\varepsilon_i\lambda/\sigma)}{1 - \Phi(\varepsilon_i\lambda/\sigma)} - \left(\frac{\varepsilon_i\lambda}{\sigma} \right) \right] \dots\dots\dots (4.9)$$

Therefore, $TE_i = \exp\{-\hat{u}_i\} = \exp\{-E(u_i/\varepsilon_i)\}$ and the variance parameters is $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2/\sigma^2$ with $0 \leq \gamma \leq 1$. The inefficiency can be measured by the parameter gamma and it is interpreted as the percentage of the variation in output whether the distributional assumption of the inefficiency effect is correctly specified or not can be checked by σ^2 . If $\gamma = 0$, all deviations from the frontier are entirely due to noise and $\gamma = 1$, all the deviations are due to technical inefficiency,

while If γ is close to one, all deviations are due to technical inefficiency (Coelli *et al.*, 2005). Mathematically the TE of the farmer $0 \leq TE_i \leq 1$ and it can be formulated as-

$$TE_i = \frac{y_i}{y_i^*} = \frac{E(y_i|x_i, u_i)}{E(y_i|x_i, u_i = 0)} = \frac{f(x_i; \beta) \exp(v_i - u_i)}{f(x_i; \beta) \exp(v_i)} = \exp(u_i) \dots\dots\dots (4.10)$$

Technical inefficiency = $(1 - TE_i)$ and the inefficiency is a linear function of explanatory variables and inefficiency variables, Z_i (Battese and Coelli, 1995).

As such the inefficiency model is a function of exogenous factors as

$$u_i = \delta Z_i + w_i, \dots\dots\dots (4.11)$$

Where Z_i is a vector of explanatory variables and δ is a vector of unknown parameters to be estimated and w_i are unobserved random variables which are assumed to be independently distributed and obtained by truncation of normal distribution with zero mean and constant variance σ_w^2 .

CHAPTER V

MODELS AND SMALL UNIT EFFICIENCY

MODELS AND SMALL UNIT EFFICIENCY

5.1. Introduction

The production efficiency refers to a level of highest capability at which all inputs are being utilized to generate the cost efficient output. A stochastic frontier production function can be employed to measure technical efficiency and its determinants. Since the econometric models could be able to specify and used to identify the determinants of technical (in)efficiency on the basis of input variables, the empirical models have been specified together with the estimation of respective (in)efficiency models for the small units selected in this study.

5.2. Units in the study

As the research is based on the primary data, the population and study area have discussed briefly in the section 4.2 with data collection methodology. Now, it is our primary we need to get involve how the Boro farmers are efficient locally or according to small units as selected by Upazilas of the study area. As therefore, the data of farmers from eight Upazilas taking two Upazilas from each selected districts; Mithapukur and Kaunia from Rangpur district, Biral and Hakimur Upazilas from Dinajpur district, Sonatala and Kahaloo from Bogura, and Singra and Baraigram from Natore district. The data from these small units have been fitted in SFA models accordingly in this chapter.

5.3. Specification of empirical models

The modeling and estimation of frontier production functions became important in the econometric research during the last few decades. Econometric models measuring technical efficiency/inefficiency specifying its determinants for the Boro producers have describe in this section.

5.3.1. Specification of production function model

In empirical literature different functional forms including the Cobb-Douglas, translog, linear, and quadratic functions were explored in analyzing efficiency. Among these, the most commonly employed models are the Cobb-Douglas and the translog production functional forms in agriculture (Kadiri *et al.*, 2014). Each functional form has its own advantage and limitations. However, translog production function specification suffers from multicollinearity problem as a result of the square and interaction terms of the inputs used (Hussain *et al.*, 2012). Therefore, a CD production function was employed to exploring the technical efficiency and affecting factors of Boro rice farmers in study area. Because the Cobb-Douglas functional form has been extensively used to represent the relationship of inputs to outputs due to ease of computation and simplicity. According to Binam *et al.*, (2005) the Cobb-Douglas production function provides an adequate representation of any given production technology. Additionally, it is efficient for multiple input modeling and provides an efficient way of handling multicollinearity, heteroscedasticity and correlation (Kavoi *et al.*, 2016). It is also convenient in interpreting elasticity of production and it is very parsimonious with respect to degrees of freedom (Wana and Lemessa, 2019). The Cobb-Douglas production function was developed by C. W. Cobb (1875-1949) and P. H. Douglas (1892-1976) in 1928. Therefore, the specified empirical model of the Cobb-Douglas production function for the Boro rice producers is-

$$Y_i = \beta_0 X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} X_6^{\beta_6} e^{\varepsilon_i} \dots\dots\dots (5.1)$$

Equation (5.1) can simplify by taking the natural logarithm and produce as-

$$\ln Y_i = \beta_0 + \sum_{j=1}^6 \beta_j \ln X_{ji} + \varepsilon_i \dots\dots\dots (5.2),$$

where,

Y_i = Amount of harvested Boro for *ith* farmer expressed in kg/bigha

X_1 = Land area under Boro rice for *ith* farmer expressed in bigha

X_2 = Amount of seed cost used by the *ith* farmer in Tk/bigha

X_3 = Amount of labour cost used by the *ith* farmer in Tk/bigha

X_4 = Amount of fertilizer cost used by the *ith* farmer in Tk/bigha

X_5 = Amount of pesticide cost used by the *ith* farmer in Tk/bigha

X_6 = Amount of harvesting cost used by the *ith* farmer in Tk/bigha

β_0 = Intercept, common to all farmers

β_j = unknown parameters to be estimated

ε_i = Random error.

5.3.2. Specification of inefficiency effect model

The determinants of technical inefficiency are modeled in terms of factors that are assumed to affect the inefficiency of Boro farmers in the study area. The inefficiency model would help one to determine the factors that improve the efficiency levels of the farmers in the study area. The inefficiency variables are the demographic and socio-economic, institutional and farm specific variables of the farmers. These variables are assumed to influence technical inefficiency of the farmers. The inefficiency model is expressed explicitly as:

$$u_i = \delta_0 + \sum_{k=1}^n \delta_k z_{ik} + \omega_i \dots\dots\dots (5.3),$$

where, u_i = technical inefficiency of the i th farmer

Z_i s are the explanatory variables for the technical inefficiency effects of the i th farmer where,

- Z_1 = Age of i th farmer (in years)
- Z_2 = Farming experience (in years) and
- Z_3 = Family size (in number) of i th farmer

ω_i s are unobserved random variables which are assumed to be independently distributed and obtained by truncation of normal distribution with zero mean and constant variance.

5.4. Likelihood Ratio (LR) test

The null hypotheses of influence of inefficiency parameters in the error frontier model are performed and tested using generalized likelihood ratio test statistic defined as-

$$\chi^2 = -2 \ln [L(H_0)/L(H_1)] = -2[\ln L(H_0) - \ln L(H_1)] \dots\dots\dots (5.4),$$

where, $L(H_0)$ and $L(H_1)$ represents the value of the likelihood function for the frontier model under the null and alternative hypotheses respectively. The test statistic has mixed chi-square distribution.

5.4.1. Statement of hypotheses

Based on the proposed study of factors affecting the technical efficiency of Boro rice producers of northern region in Bangladesh and the defined objectives, the hypothesis is as-

Hypothesis-1: The CD stochastic production function is robust and adequate representation of the frontier production function.

$$H_0 : \beta_{ij} = 0.$$

Hypothesis-2: Boro rice producers in northern region are not technically inefficient and no remarkable production loss is attained to the inefficient model.

$$H_0 : \gamma = 0 .$$

Hypothesis-3: Both the parameters of the stochastic frontier and the inefficiency model are jointly zero such that the variables included under the inefficiency effects model are not jointly affecting technical inefficiency of the Boro rice producers in northern region.

$$H_0 : \gamma = \delta_0 = \delta_j = 0 \text{ for all } j$$

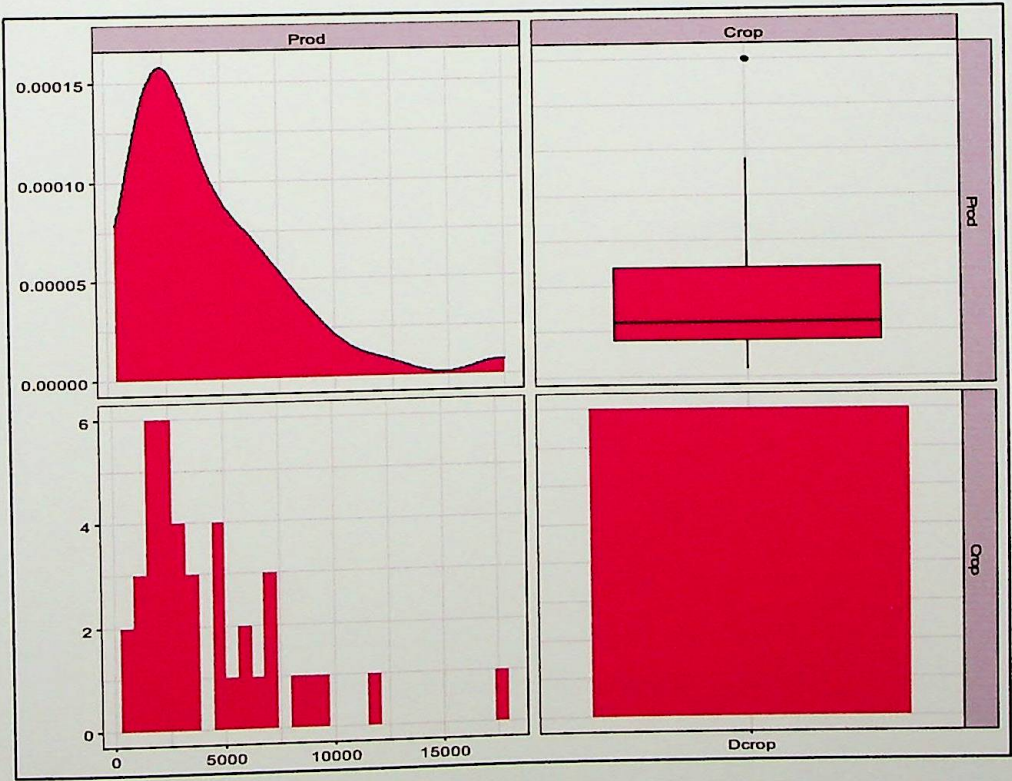
5.5. Characteristics of small unit variables

A set of input variables have used in this research (see section 4.4.2) makes it easy to catching the common characteristics of the data are discussed in this section considering Upazilas as small unit.

Production of Boro rice of the selected Upazilas have plot according to the cropping pattern, Mono (MCrop), Di (DCrop) and Tri (TCrop) and are given in the Figure 5.1 for Rangpur and Dinajpur, and in the Figure 5.2 for Natore and Bogura. Density and Quintile plots are shown in the figures from Figure 5.3 to Figure 5.6 respectively for the Upazilas of districts Rangpur, Dinajpur, Natore and Bogura.



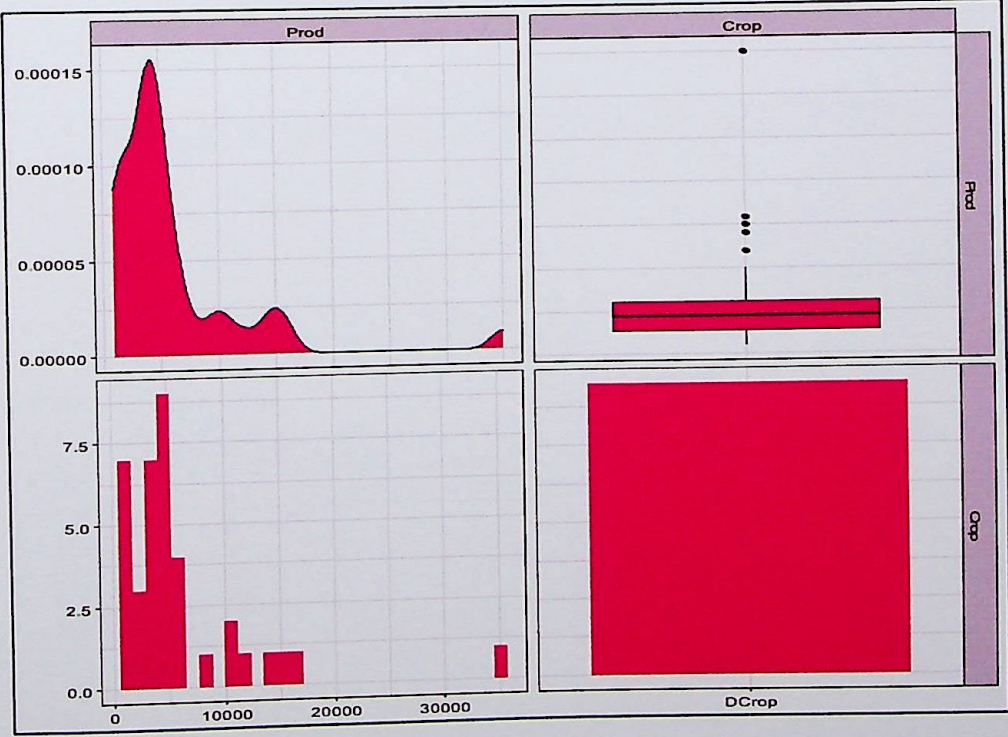
(a) Kaunia Upazila of Rangpur district



(b) Mithapukur Upazila of Rangpur district



(c) Biral Upazila of Dinajpur district



(d) Hakimpur Upazila of dinajpur district

Figure 5.1: Production plot by cropping pattern of Rangpur and Dinajpur
(Source: Author's surveyed data)



(a) Singra Upazila of Natore district



(b) Baraigram Upazila of Natore district



(c) Kahaloo Upazila of Bogura district



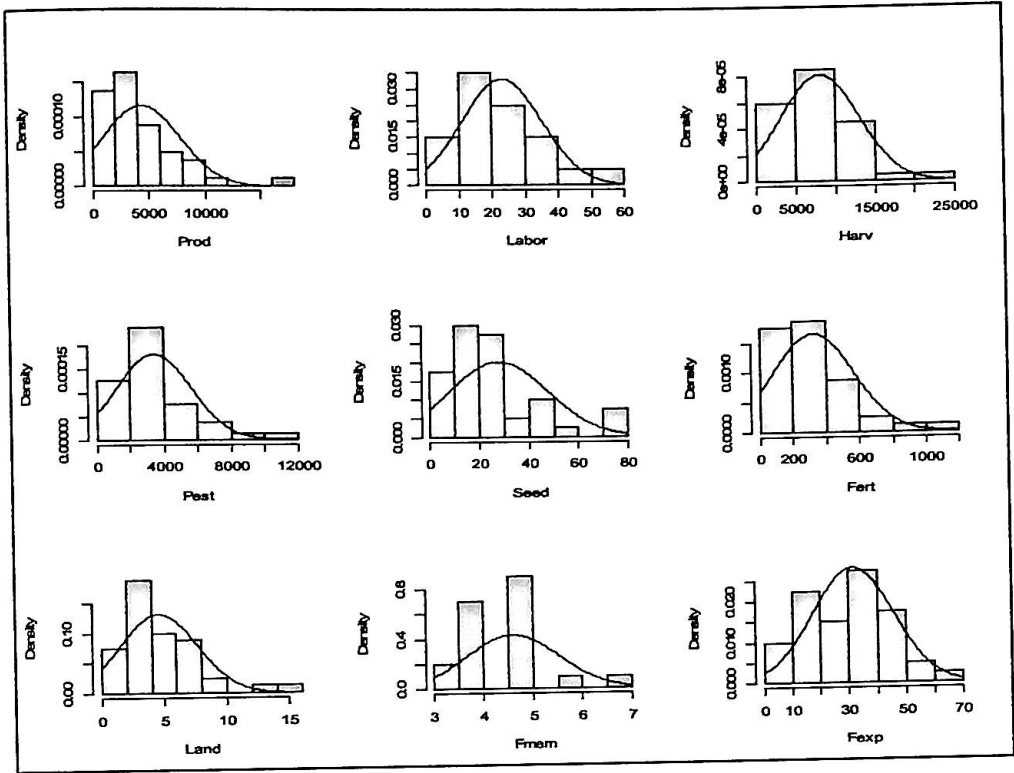
(d) Sonatola Upazila of Bogura district

Figure 5.2: Production plot by cropping pattern of Natore and Bogura

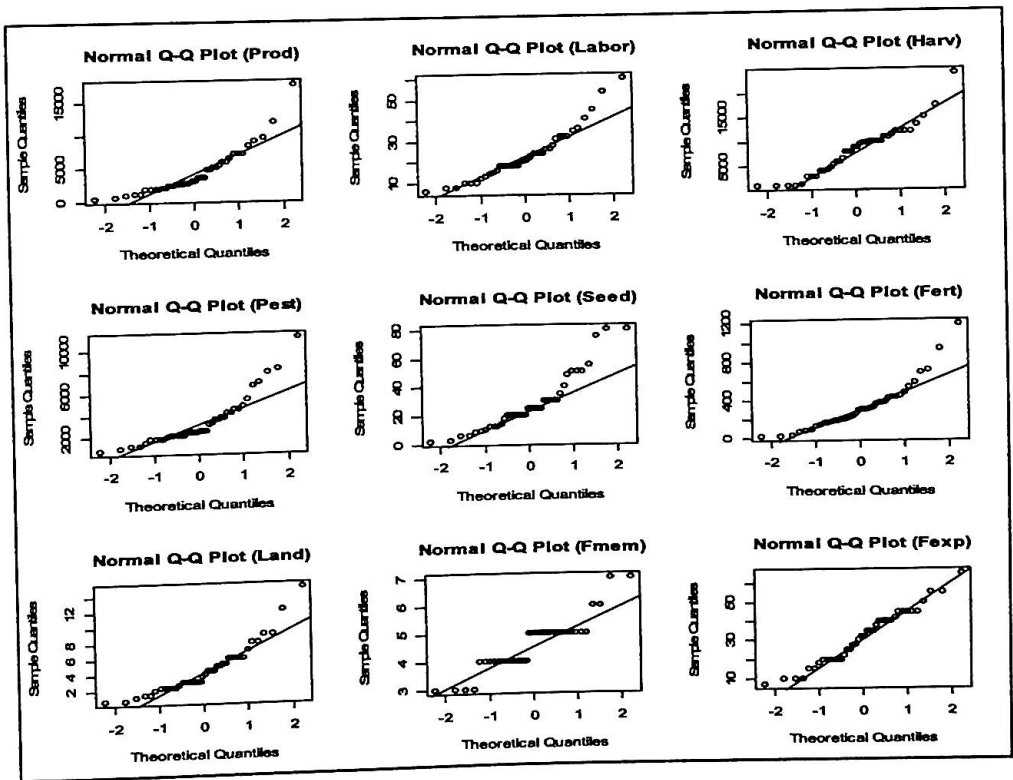
(Source: Author's surveyed data)

The Figure 5.1 (a) of Kaunia Upazila is cultivating MCrop, DCrop and TCrop. The MCrop and TCrop having the bimodal distribution. However, farmers of Mithapukur Upazila are cultivating only DCrop evident from Figure 5.1 (b). The maximum number of farmers are occupied their land with DCrop while a very few numbers have found in the MCrop category. However, a group of outlying production has been evident from the Figure 5.1(c) for Biral Upazila of Dinajpur District. The farmers of Hakimpur Upazila of Dinajpur District are growing only DCrop. There are five outliers including one high potential observation have been demonstrated in the Figure 5.1(d).

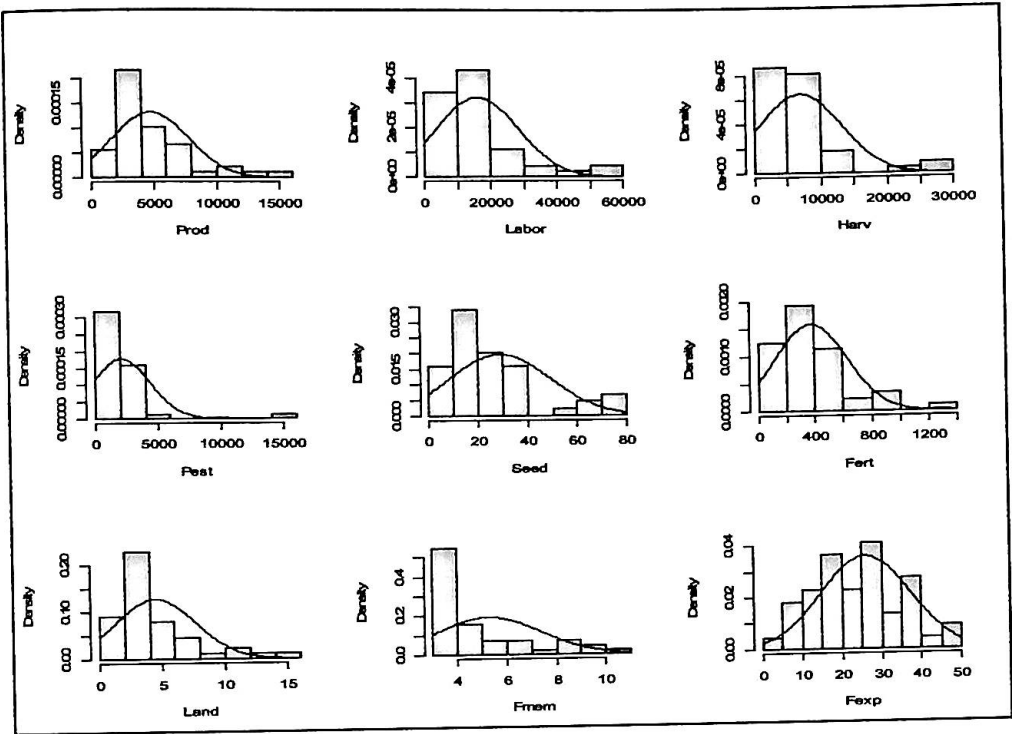
It is depicted from the Figure 5.2 (a) that production of Boro rice practices lies in two cropping category like, DCrop and MCrop and MCrop showing highest production range with a bimodal nature for Singra Upazila. Two outlying observations for DCrop and one for MCrop are identified here. Same characteristics are showing for Barigram Upazila in Figure 5.2 (b). DCrop and TCrop practices by the farmers of Kahalu demonstrated from the Figure 5.2 (c) and productions of the cropping category showing somewhat normal behaviour. It observed from Figure 5.2 (d) that three assigned patterns occupying among the farmers of Sonatola Upazila of Bogura district and DCrop occurring two outlying observations. Further the DCrop and TCrop posses the bimodal nature for this Upazila. The MCrop is very insignificant in this data set.



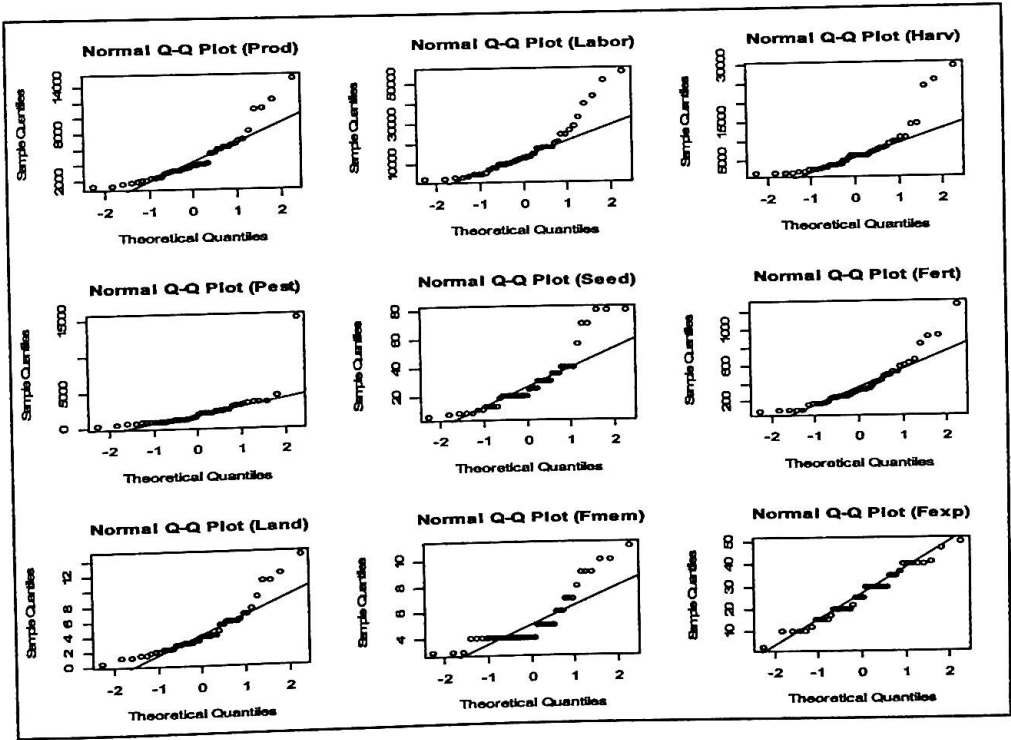
(a) Density plot of variables of Mithapukur



(b) Quintile plot of variables of Mithapukur



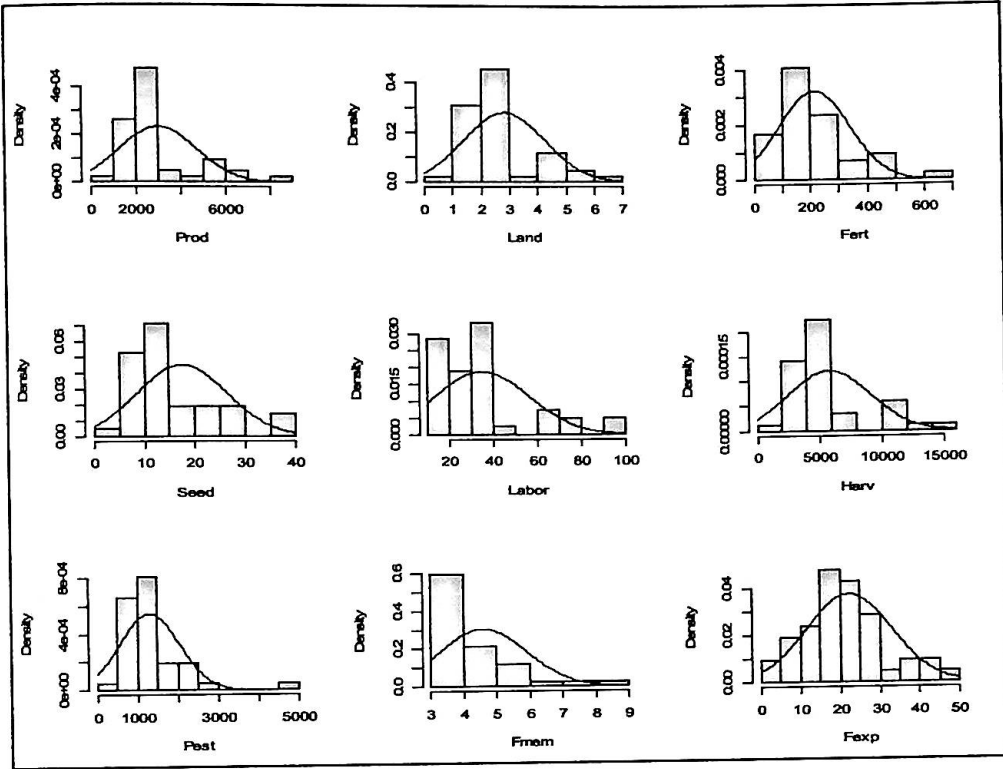
(c) Density plot of variables of Kaunia



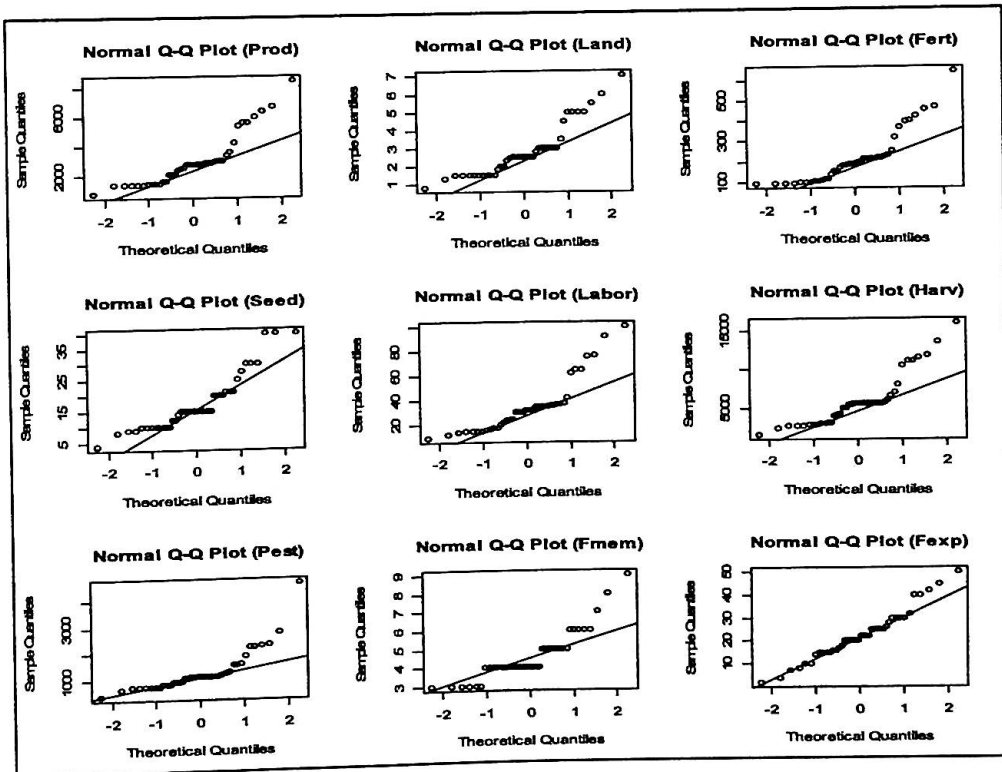
(d) Quintile plot of variables of Kaunia

Figure 5.3: Density plot and quintile plot for Rangpur

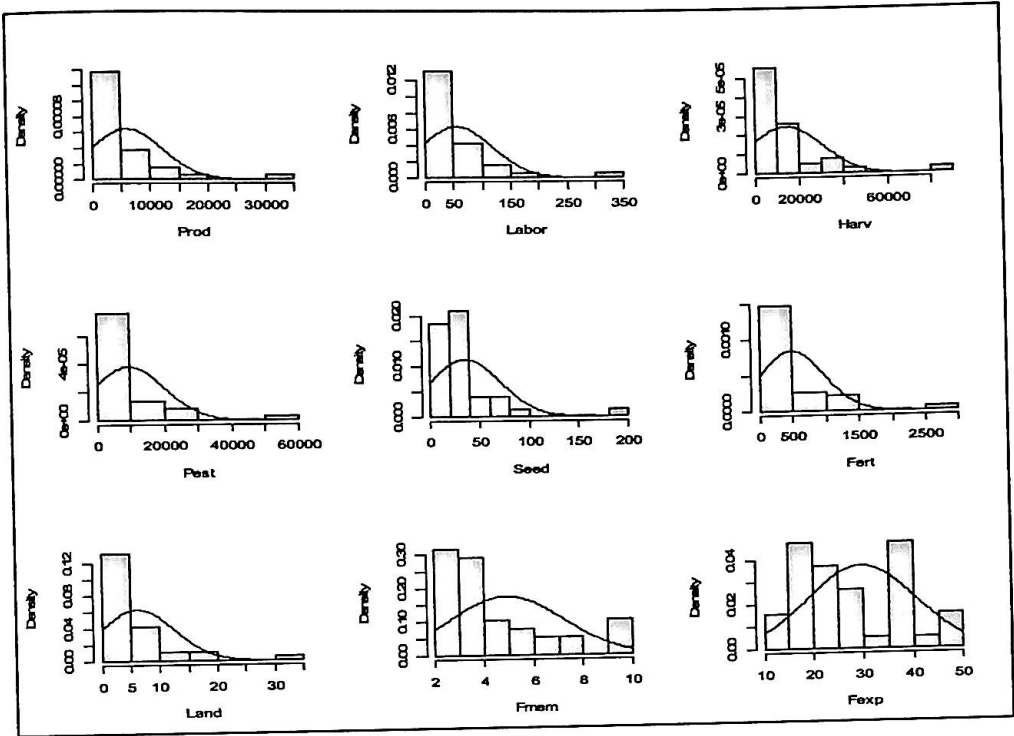
(Source: Author’s surveyed data)



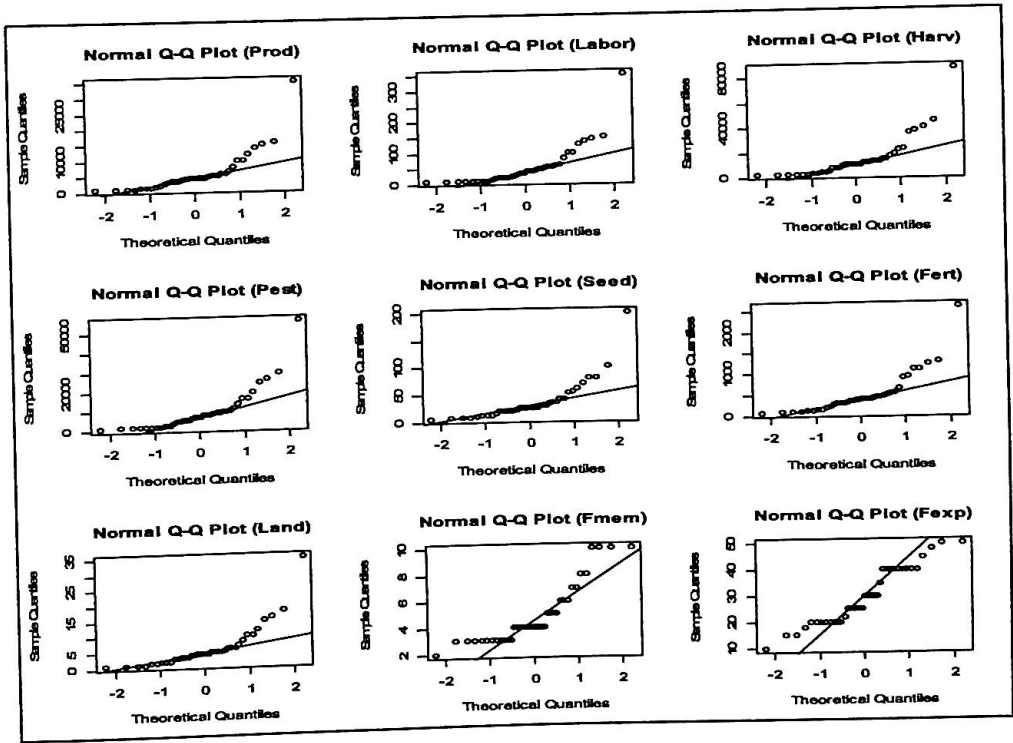
(a) Density plot of variables of Biral



(b) Quintile plot of variables of Biral



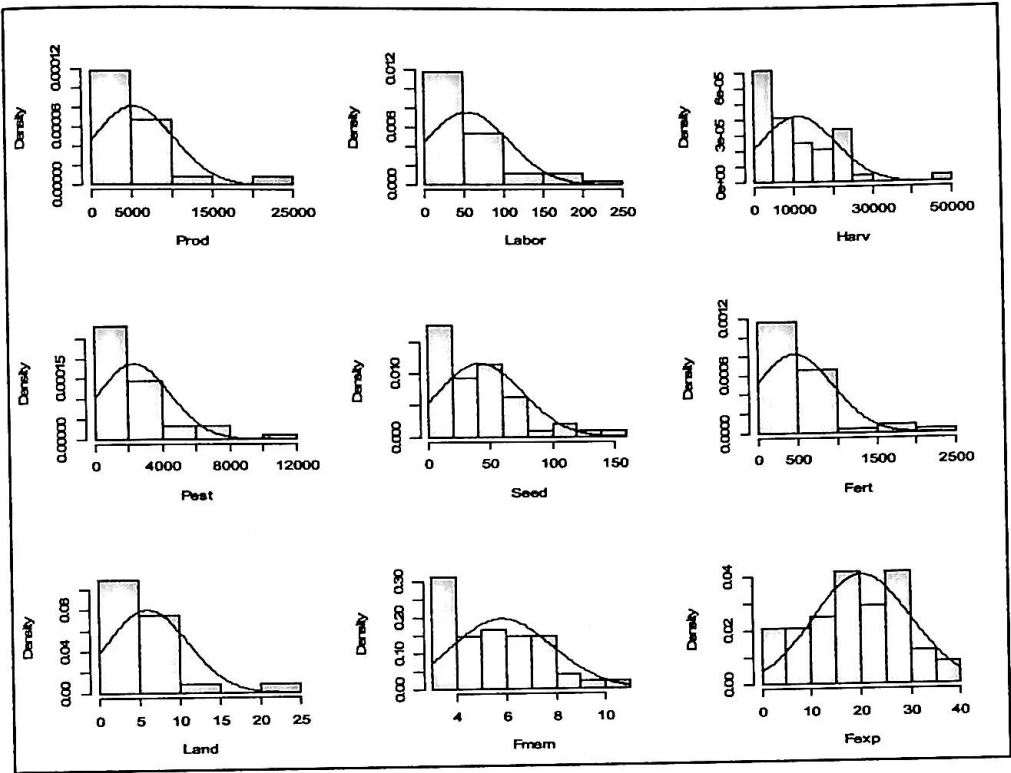
(c) Density plot of variables of Hakimpur



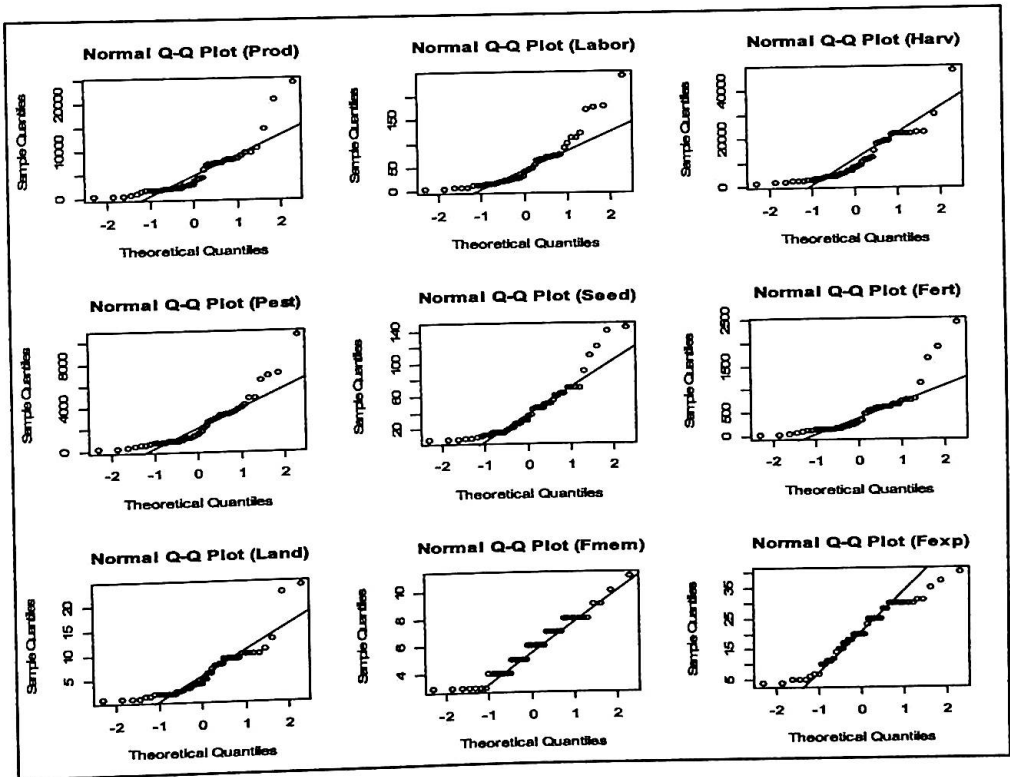
(d) Quintile plot of variables of Hakimpur

Figure 5.4: Density plot and Quintile plot for Dinajpur

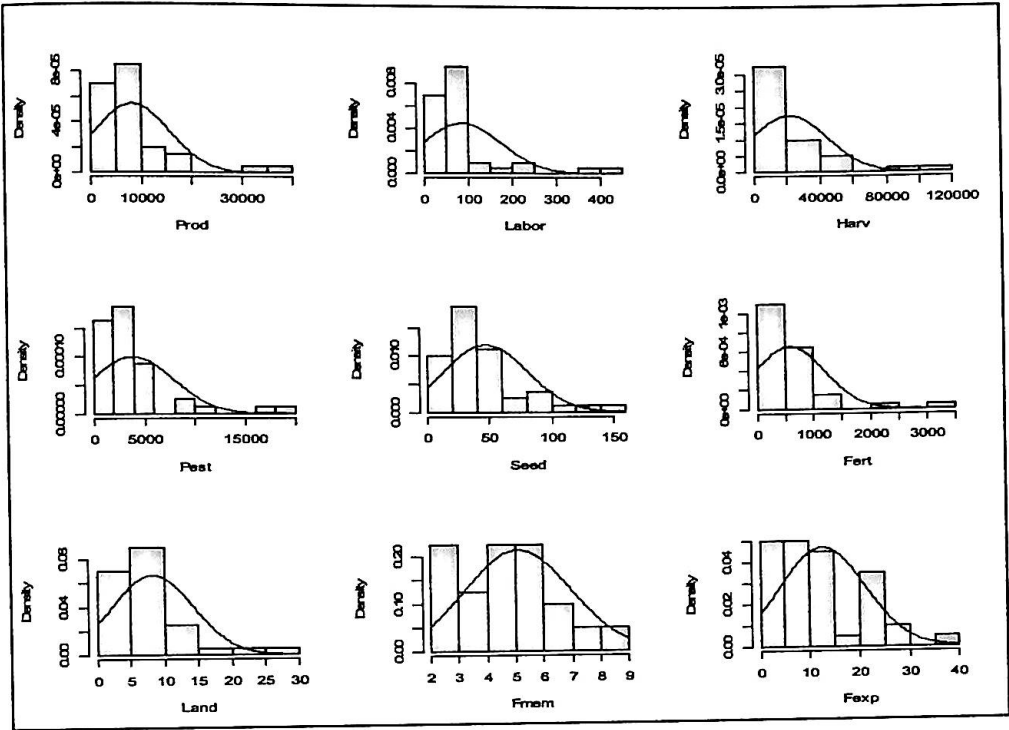
(Source: Author's surveyed data)



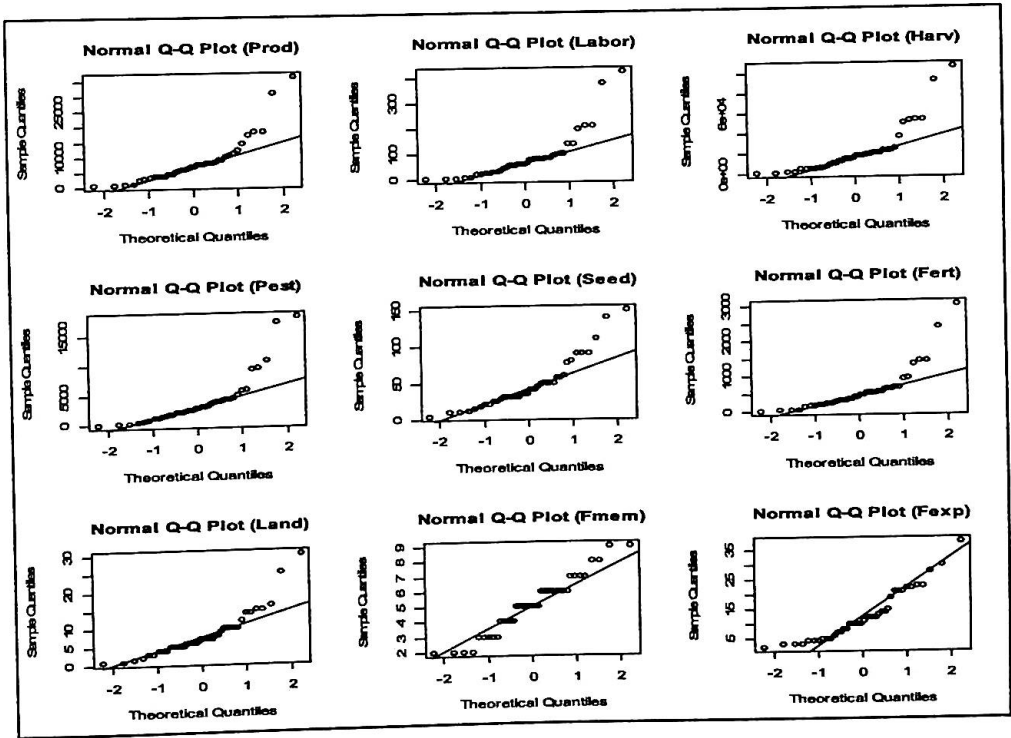
(a) Density plot of variables of Singra



(b) Quintile plot of variables of Singra

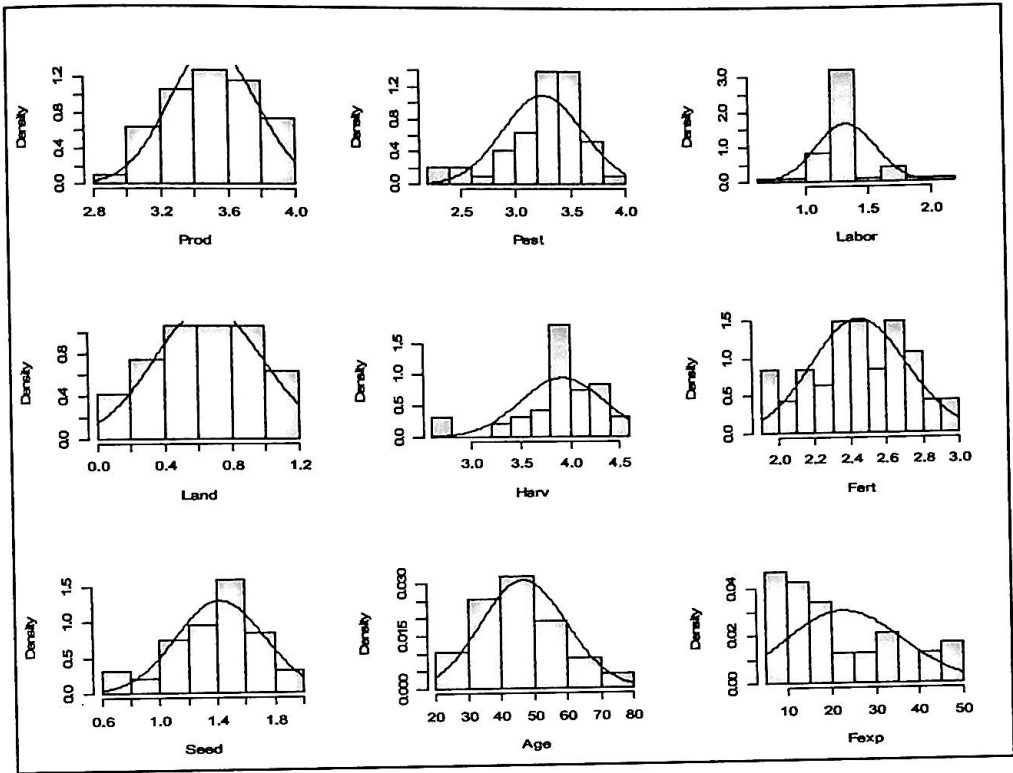


(c) Density plot of variables of Baraigram

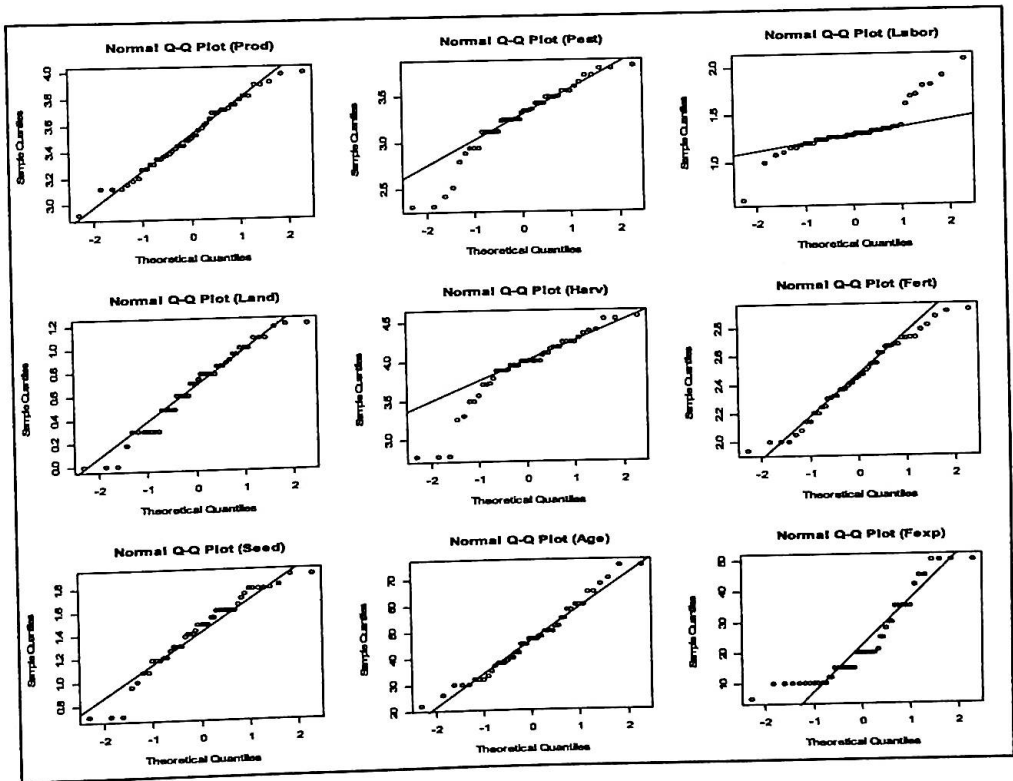


(d) Quintile plot of variables of Baraigram

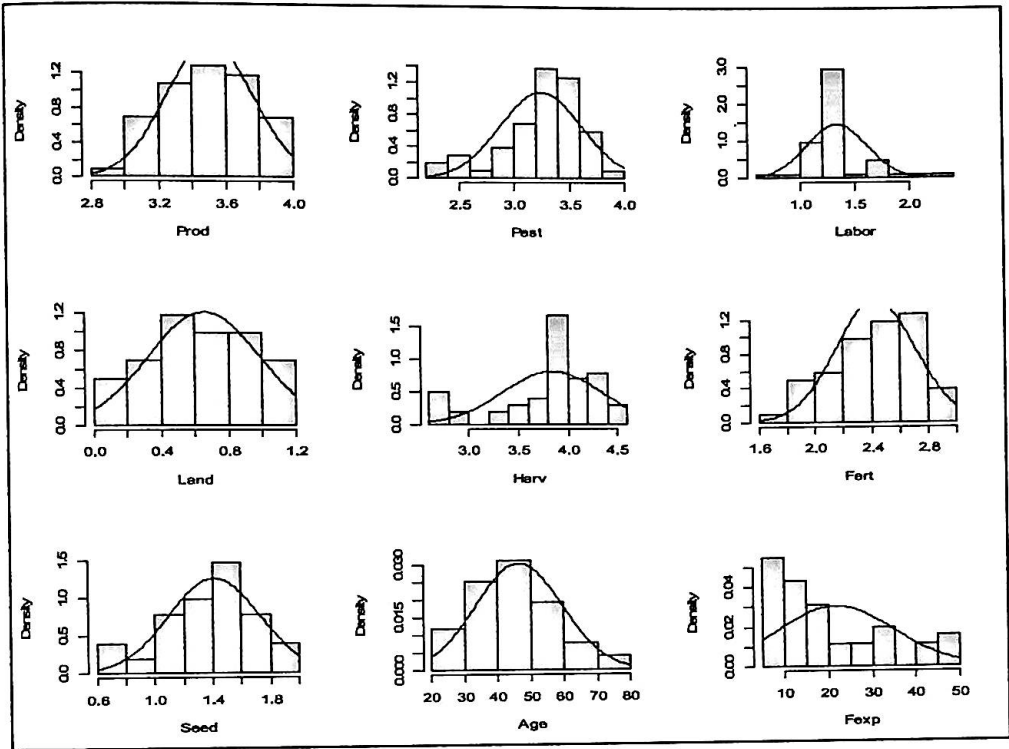
Figure 5.5: Density plot and quintile plot for Natore
(Source: Author’s surveyed data)



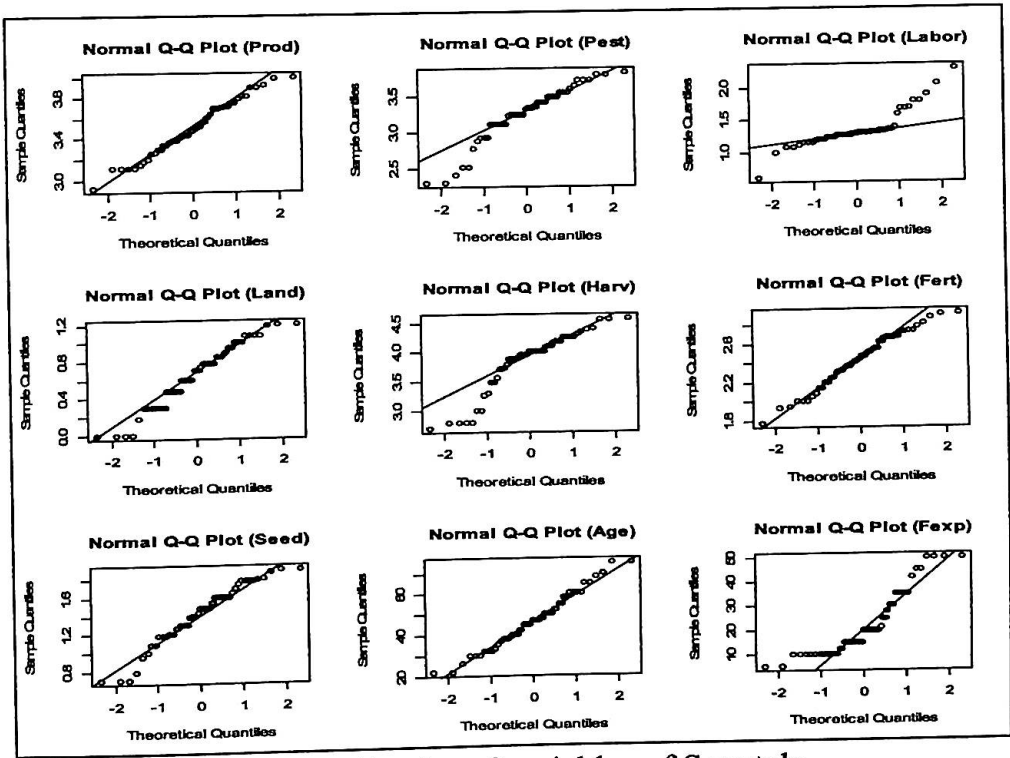
(a) Density plot of variables of Kahaloo



(b) Quintile plot of variables of Kahaloo



(c) Density plot of variables of Sonatala



(d) Quintile plot of variables of Sonatala

Figure 5.6: Density plot and quintile plot for Bogura
(Source: Author’s surveyed data)

Although non-normality of errors are somewhat witnessed for all the observations in the study a relative discussion have made. Except Fexp all other variables have right skewed pattern are seen from Figure 5.5 (a). The quintile plots of variables of Singra Upazila having non-normal behaviour are evident from Figure 5.5 (b). In Mithapukur, among the variables Seed and Pest are showing remarkable non-normality by 5.3(a). The Labour and Seed are seen to behave non-normal errors for Kaunia. The Land, Lab and Harv for Biral and the Seed, Land and Harv for Hakimpur of Dinajpur are showing non-normality that assured by quartile plot in Figure 5.4(b) and Figure 5.4(d). The quintile plots of variables of Singra Upazila having non-normal behaviour are evident from Figure 5.5 (b) and Figure 5.5 (d).

The variables Fert, Harv and Fexp are deviating from the normal are seen in the Figure 5.6 (c) for Sonatala but for Kahaloo only Harv is seen to be non-normally distributed in Figure 5.6 (a). The quintile plots of errors of variables Pest, Labor and Harv are showing non-normal behaviour for both Kahaloo and Sonatala Upazilas in Bogura evident from Figure 5.6 (b) and Figure 5.6 (d).

5.6. Computation of small unit efficiency

The Maximum Likelihood Estimation of parameters of Eq.(5.2) using the CD stochastic production frontier for Boro rice farmers of Khaloo and Sonatala Upazila of Bogura district are given in Table 5.1 to Table 5.2.

Table 5.1: ML estimates for CD production function of Kahaloo Upazila.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	0.460	0.201	2.289	0.022
Labor	-0.025	0.031	-0.781	0.435
Harv	0.011	0.027	0.403	0.687
Pest	0.180	0.054	3.320	0.001
Seed	-0.163	0.084	-1.948	0.051
Fert	1.178	0.070	16.869	0.000
Land	-0.223	0.109	-2.042	0.041
Variance parameter				
Sigma Square	0.004	0.001	3.078	0.002
Gamma	0.847	0.132	6.442	0.000
Log likelihood	82.936			
Mean TE	0.95			
<i>n</i>	47			

(Source: Author's surveyed data)

From the above table, it is observed that Pesticide and Fertilizer are found positively significant whereas the seed and Land are found to be negatively significant for the Boro producer in Kahaloo Upazila of Bogura district. The estimated coefficients of CD production function indicate that 1% increase in Pesticide and Fertilizer cost may increase the Boro rice production by 0.18% and 1.178%, respectively. On the other hand, 1% increase in Seed and Land may decrease the Boro production by 0.163% and 0.223% respectively. The coefficient of Fertilizer (1.178) indicated that it is an important determinant in this area. As result Boro rice production is relatively more sensitive to fertilizer utilization than other inputs.

The results show that the technical efficiency of Boro rice production is on average 0.95 indicating good contribution of such small unit of production. Apparently the estimated square sigma square (σ^2) was 0.004 and it is significantly different from zero at 1% level. This indicates a good fit and the correctness of the specified distributional assumption of the composite error. Moreover the estimated gamma parameter (γ) is 0.847 and also significant at 1% level, indicating that 84.7% of the variation in the total output of production among the sampled farmers is due to differences in their technical efficiencies in Kahaloo Upazila.

Table 5.2: ML estimates for CD production function of Sonatala Upazila.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	1.439	0.469	3.068	0.002
Labor	0.125	0.151	0.828	0.408
Harv	0.300	0.051	5.862	0.000
Pest	-0.001	0.053	-0.012	0.990
Seed	0.341	0.257	1.325	0.185
Fert	0.210	0.181	1.161	0.246
Land	0.026	0.291	0.091	0.927
Variance parameter				
Sigma Square	0.012	0.003	4.804	0.000
Gamma	0.000	0.054	0.002	0.999
Log likelihood	39.594			
Mean TE	0.999			
n	51			

(Source: Author’s surveyed data)

As indicated in Table 5.2, the results show that the estimated coefficients of all the variables considered in the production model are insignificant except for the Harvesting cost. The coefficient of harvesting was 0.3 and statistically significant at 1%. This implies that 1% increase in harvesting cost may increase the Boro rice production by 0.3%. Further the variance parameter sigma squared (σ^2) indicates the goodness of fit of the specified distributional assumptions of the composite error was observed to be positive and significant at 1% but the estimated gamma (γ) = 0, it means that the output level of the frontier in the model is completely caused by the random disturbance term. That is to say, we do not need to adopt the stochastic frontier analysis method at this time.

The estimators of model Eq.(5.2) Baraigram and Singra Upazilas of Natore district are given in the tables Table 5.3 and Table 5.4.

Table 5.3: ML estimates for CD production function of Baraigram Upazila.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	1.086	0.184	5.908	0.000
Labor	0.124	0.041	3.037	0.002
Harv	0.293	0.115	2.558	0.010
Pest	0.233	0.052	4.477	0.000
Seed	0.278	0.035	8.001	0.000
Fert	0.024	0.079	0.300	0.764
Land	0.001	0.002	0.386	0.699
Variance parameter				
Sigma Square	0.002	0.001	2.615	0.009
Gamma	0.869	0.151	5.759	0.000
Log likelihood	83.937			
Mean TE	0.960			
<i>n</i>	40			

(Source: Author's surveyed data)

The results suggest that the estimated coefficients of Labor, Harvesting, Pesticide and Seed were positive and statistically significant at 1% level. It means that there is a scope for increasing the production of Boro rice by increasing the level of these inputs. Positive coefficient value of fertilizer and land were not significant. In addition, the estimated sigma square (σ^2) parameter (0.002) is significantly different from zero. This indicates a good fit of the model and the correctness of the specified distributional assumptions of the composite error terms. The estimated gamma (γ)

parameter is 0.869 which means that almost 87% of the variations in the Boro rice output among farmers in the study area are due to the differences in their technical efficiencies. It can also be explain as that the inefficiency component contribute 87% in the composite error term. In other word, it also suggests that there are about 13% of the variation was due to uncertainty or random shocks beyond the farmers control.

Table 5.4: ML estimates for CD production function of Singra Upazila.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	1.117	0.220	5.087	0.000
Labor	0.246	0.078	3.147	0.002
Harv	0.074	0.048	1.538	0.124
Pest	0.483	0.108	4.474	0.000
Seed	-0.001	0.051	-0.022	0.982
Fert	0.087	0.054	1.612	0.107
Land	0.008	0.003	2.827	0.005
Variance parameter				
Sigma Square	0.004	0.002	1.725	0.085
Gamma	0.602	0.288	2.090	0.036
Log likelihood	78.379			
Mean TE	0.963			
<i>n</i>	48			

(Source: Author's surveyed data)

The results of Table 5.4 demonstrate that the coefficients of Labor, Pesticide and Land are found to be positive and significant at 1% level. It informs that these variables were important in explaining Boro rice production in Singra Upazila. Rest of the variables, such as Harvesting, seed and Fertilizer are found to be insignificant.

The estimated variance parameters sigma square (σ^2) parameter (0.004) is significantly different from zero and this indicates a good fit of the model and the correctness of the specified distributional assumptions. Gamma (γ) is also a measure of the level of the inefficiency in the variance parameter and it is estimated as (0.602) and is significant at 5% level indicating that 60% of the total variations in Boro rice output are due to technical inefficiencies in Singra Upazila.

The ML estimates of the CD production functional of stochastic frontier model Eq. (5.2) of Boro producers for the Upazilas of Dinajpur districts are enlisted in the tables Table 5.5. and Table 5.6.

Table 5.5: ML estimates for CD production function of Biral Upazila.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	0.228	0.985	0.231	0.817
Labor	0.056	0.967	0.058	0.954
Harv	0.780	0.775	1.006	0.315
Pest	0.049	0.853	0.058	0.954
Seed	-0.013	0.979	-0.014	0.989
Fert	0.027	0.921	0.030	0.976
Land	0.139	0.997	0.139	0.889
Variance parameter				
Sigma Square	0.002	0.982	0.002	0.999
Gamma	0.657	1.000	0.657	0.511
Log likelihood	94.086			
Mean TE	0.971			
n	42			

(Source: Author’s surveyed data)

Table 5.6: ML estimates for CD production function of Hakimpur Upazila.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	2.053	0.996	2.061	0.039
Labor	-0.028	0.990	-0.028	0.978
Harv	0.011	0.938	0.012	0.990
Pest	-0.002	0.945	-0.003	0.998
Seed	0.083	0.992	0.084	0.933
Fert	0.451	0.975	0.463	0.644
Land	0.499	0.998	0.500	0.617
Variance parameter				
Sigma Square	0.001	0.568	0.002	0.998
Gamma	0.608	1.000	0.608	0.543
Log likelihood	96.290			
Mean TE	0.982			
n	38			

(Source: Author’s surveyed data)

The results obtained from Table 5.5 - Table 5.6 have identified no such variables are significant including constant. It may be due to very small observations 42 and 38 respectively or some other hidden causes may involve which are needed to investigate. As the diagnostic statistics of the variance parameter, sigma-squared (σ^2) and the estimated variance ratio parameter gamma (γ) are statistically insignificant the result could not be reliable for Biral and Hakimpur Upazilas of Dinajpur.

Small unit efficiency of Boro farmers of Rangpur district are computed and presented in the tables Table 5.7 - Table 5.8.

Table 5.7: ML estimates for CD production function of Kaunia Upazila.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	1.457	0.183	7.965	0.000
Labor	0.172	0.084	2.040	0.041
Harv	0.024	0.023	1.050	0.294
Pest	-0.002	0.023	-0.073	0.942
Seed	0.100	0.077	1.304	0.192
Fert	0.482	0.093	5.206	0.000
Land	0.010	0.003	2.936	0.003
Variance parameter				
Sigma Square	0.002	0.001	2.381	0.017
Gamma	0.628	0.300	2.096	0.036
Log likelihood	86.993			
Mean TE	0.973			
<i>n</i>	44			

(Source: Author's surveyed data)

From the results, it is clear that the variables Labor, Fertilizer and Land are significant at 1% and 5% levels. But the variables seed, pesticide and harvesting cost are not statistically significant at the conventional level. The coefficient of Land is positive and significant indicates that an upsurge in Land would lead to an increase in Boro rice production. The coefficient of Labor shows that increased effect of Labor would increase Boro rice output. Similar effect of fertilizer is found in this analysis.

Further the diagnostic statistics of inefficiency component reveals that the variance parameter sigma squared (σ^2) is found to be positive and statistically significant at 1%, which indicates goodness of fit and the correctness of the distributional form are marked herewith. The estimated variance ratio parameter gamma (γ) of 0.628 and statistically significant at 1% level meant that about 62.8% of the variation in total Boro rice output was due to differences in technical efficiency and that the variation in output was not solely due to random effects.

Table 5.8: ML Estimates for CD production function of Mithapukur Upazila

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	1.615	0.247	6.530	0.000
Labor	0.151	0.152	0.997	0.319
Harv	0.028	0.048	0.598	0.550
Pest	0.033	0.090	0.373	0.709
Seed	-0.050	0.118	-0.423	0.672
Fert	0.625	0.098	6.404	0.000
Land	0.030	0.009	3.274	0.001
Variance parameter				
Sigma Square	0.013	0.008	1.576	0.115
Gamma	0.906	0.264	3.431	0.001
Log likelihood	48.607			
Mean TE	0.917			
n	40			

(Source: Author’s surveyed data)

The results in above table showed that inputs like Land and Fertilizer (at 1% significance level) allocated for Boro rice were found to positively and significantly explained the level of efficiency of Boro rice production, which are important variables in shifting the frontier output to the right. This indicated that at each and every unit of these variables there is a possibility to increase the level of output. The coefficients for cost of Labor, Harvesting, Pesticide and Seed cost were not statistically significant, implying that these variables are not important factors affecting output of Boro rice farmers in Mithapukur Upazila of Rangpur district.

The variance parameter sigma square (σ^2) is positive and significant at 10%. This indicates the goodness of the specified distributional assumptions of the composite error. This is also evident from the estimated gamma (γ) of 0.906, which is close to one. This confirms that the technical inefficiency effects are significant in the estimated model.

As we are interested to the small unit, efficiency we have been examined the distribution for all eight Upazilas. The results of the Upazila are presented in the figures, Figure 5.7- Figure 5.14.

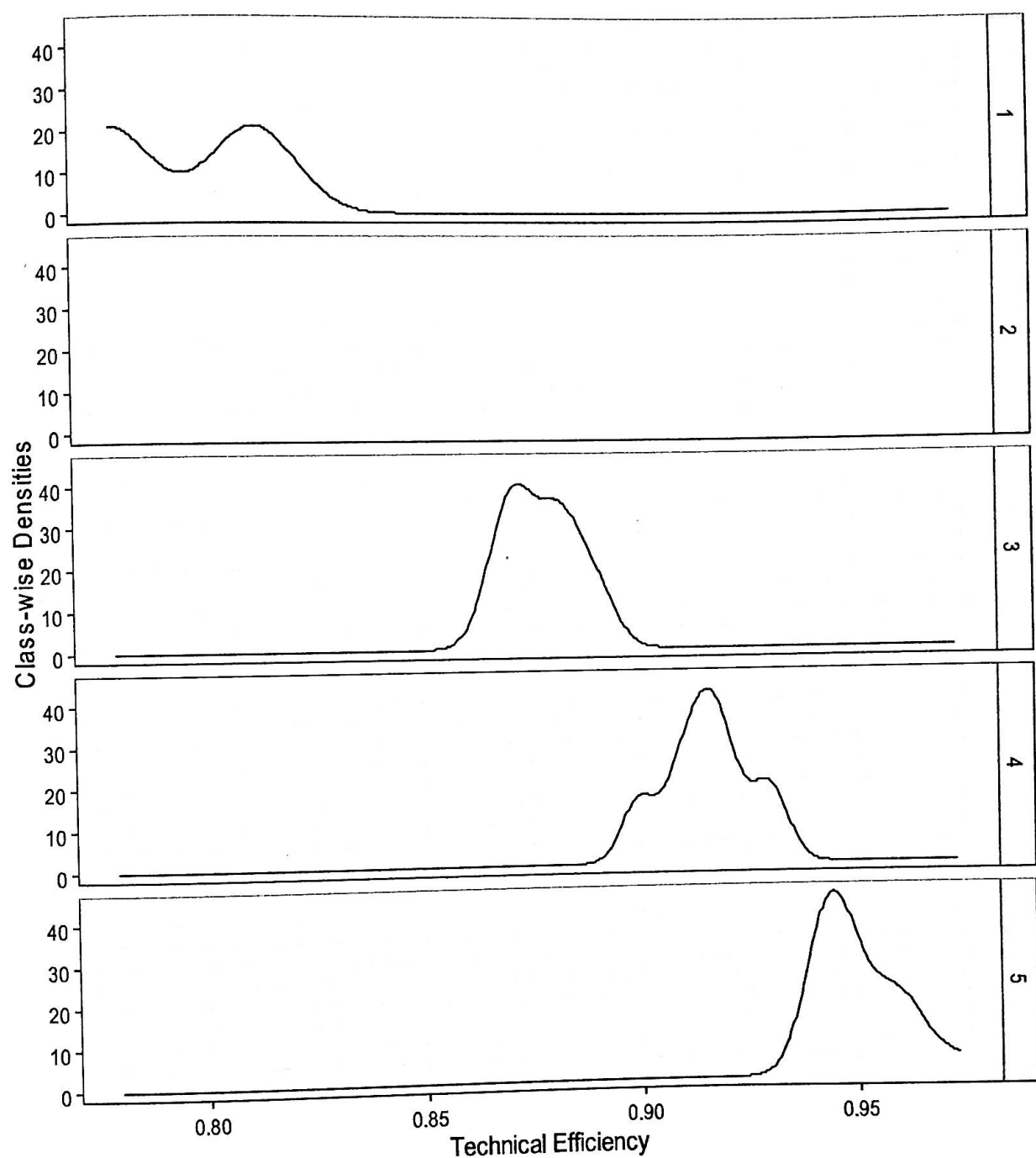


Figure 5.7: Stage wise estimated TE of Boro farmers of Singra

(Source: Author's surveyed data)

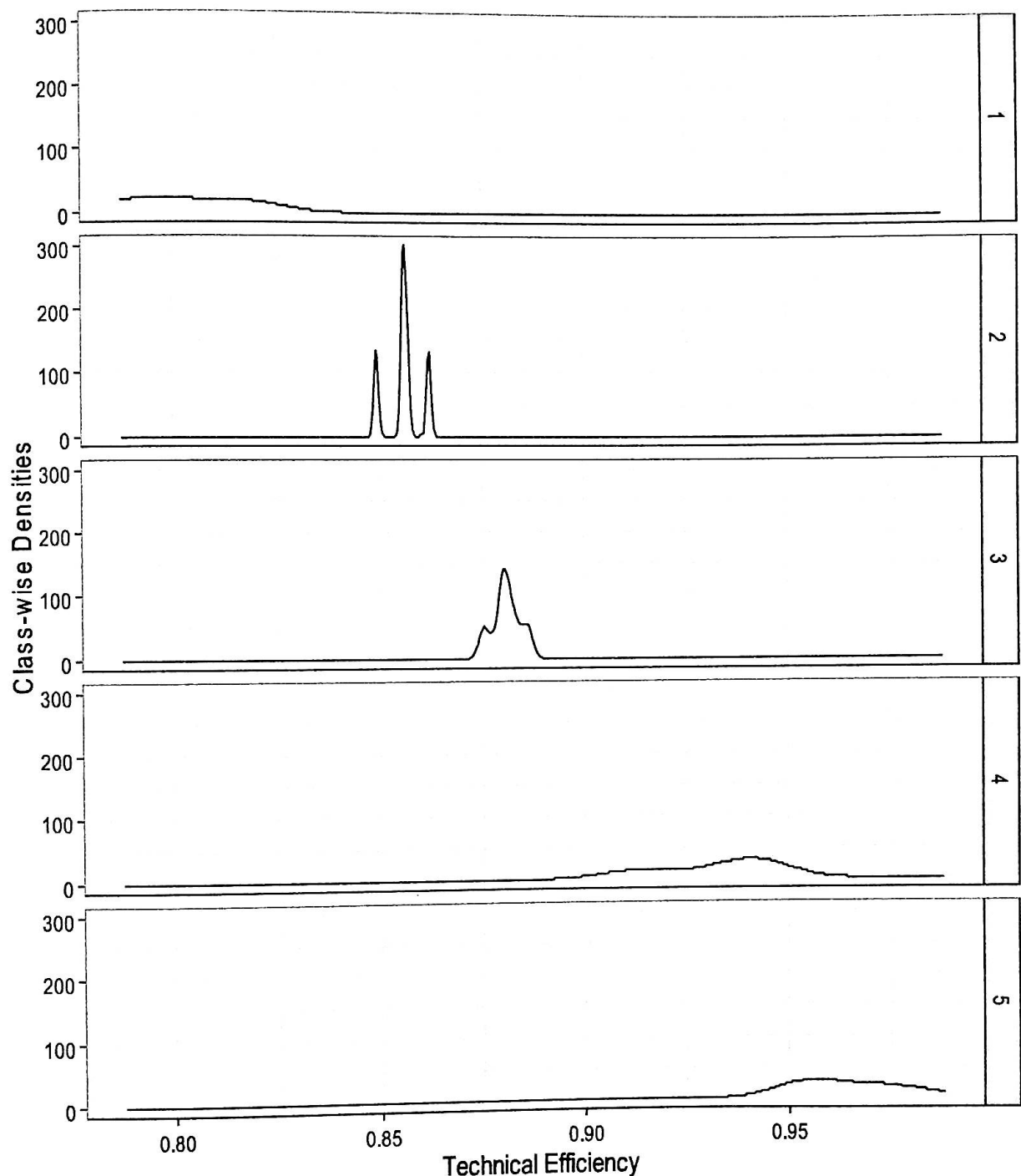


Figure 5.8: Stage wise estimated TE of Boro farmers of Baraigram

(Source: Author's surveyed data)

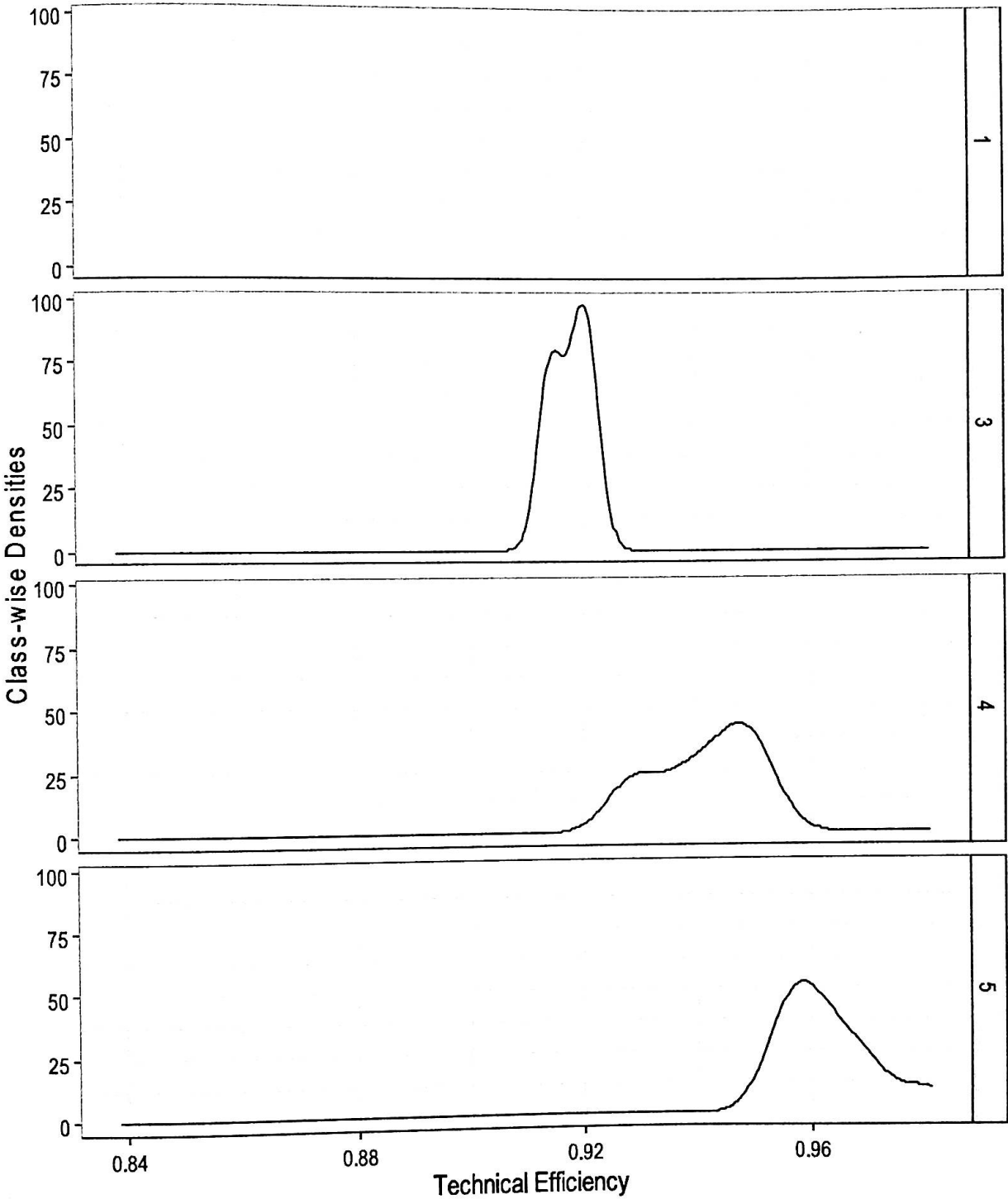


Figure 5.9: Stage wise estimated TE of Boro farmers of Kaunia
(Source: Author’s surveyed data)

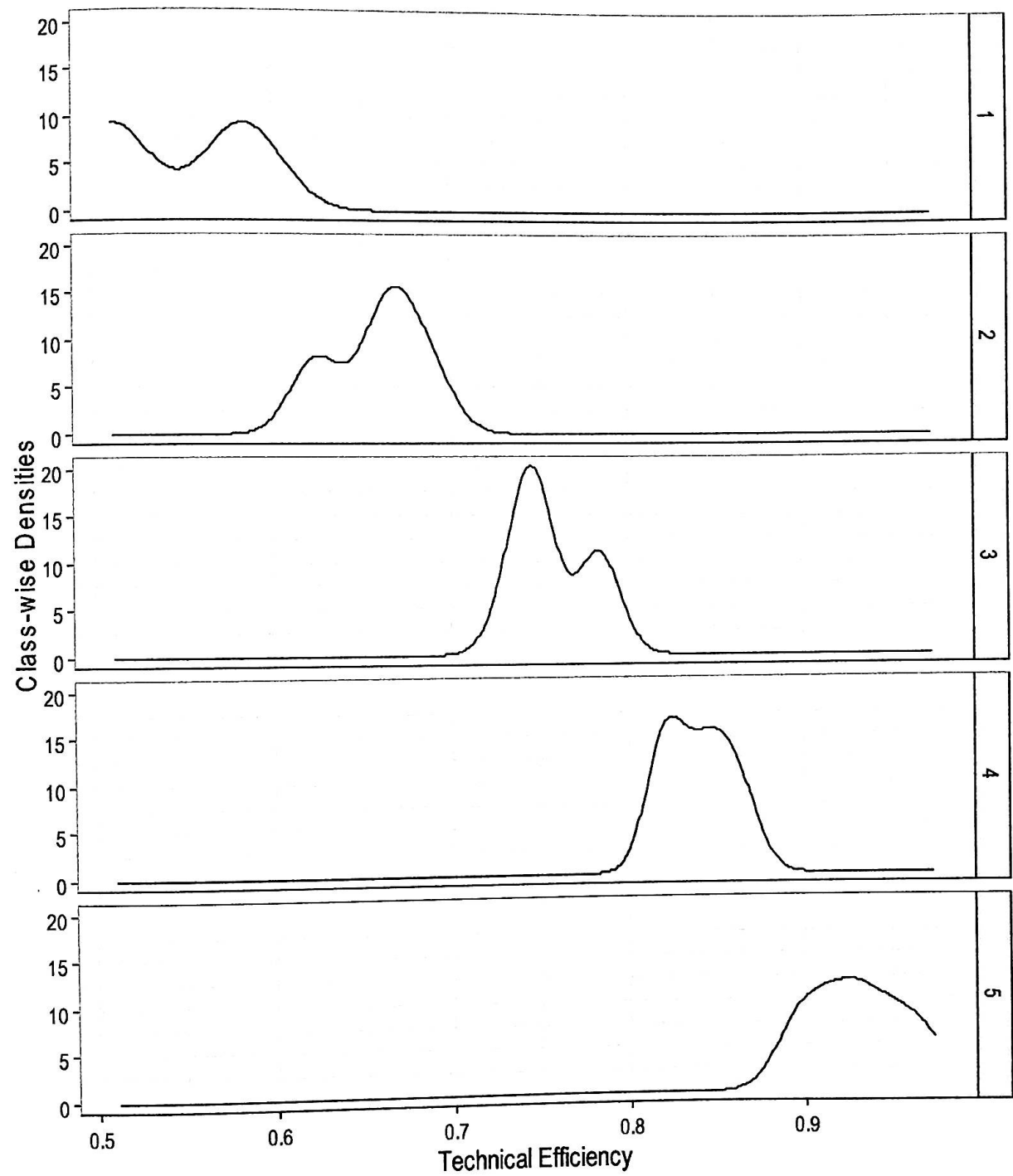


Figure 5.10: Stage wise estimated TE of Boro farmers of Mithapukur

(Source: Author's surveyed data)

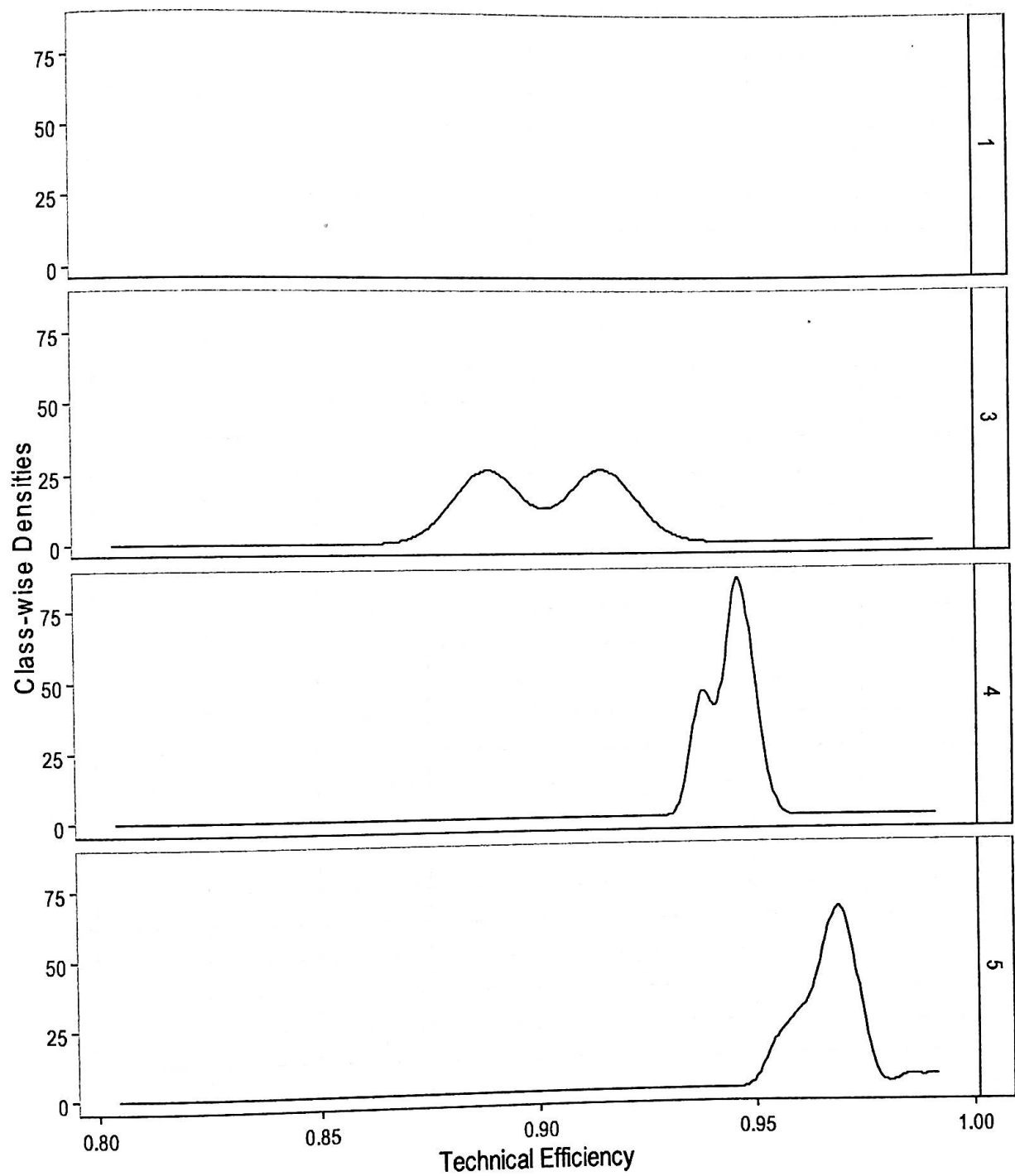


Figure 5.11: Stage wise estimated TE of Boro farmers of Biral

(Source: Author's surveyed data)

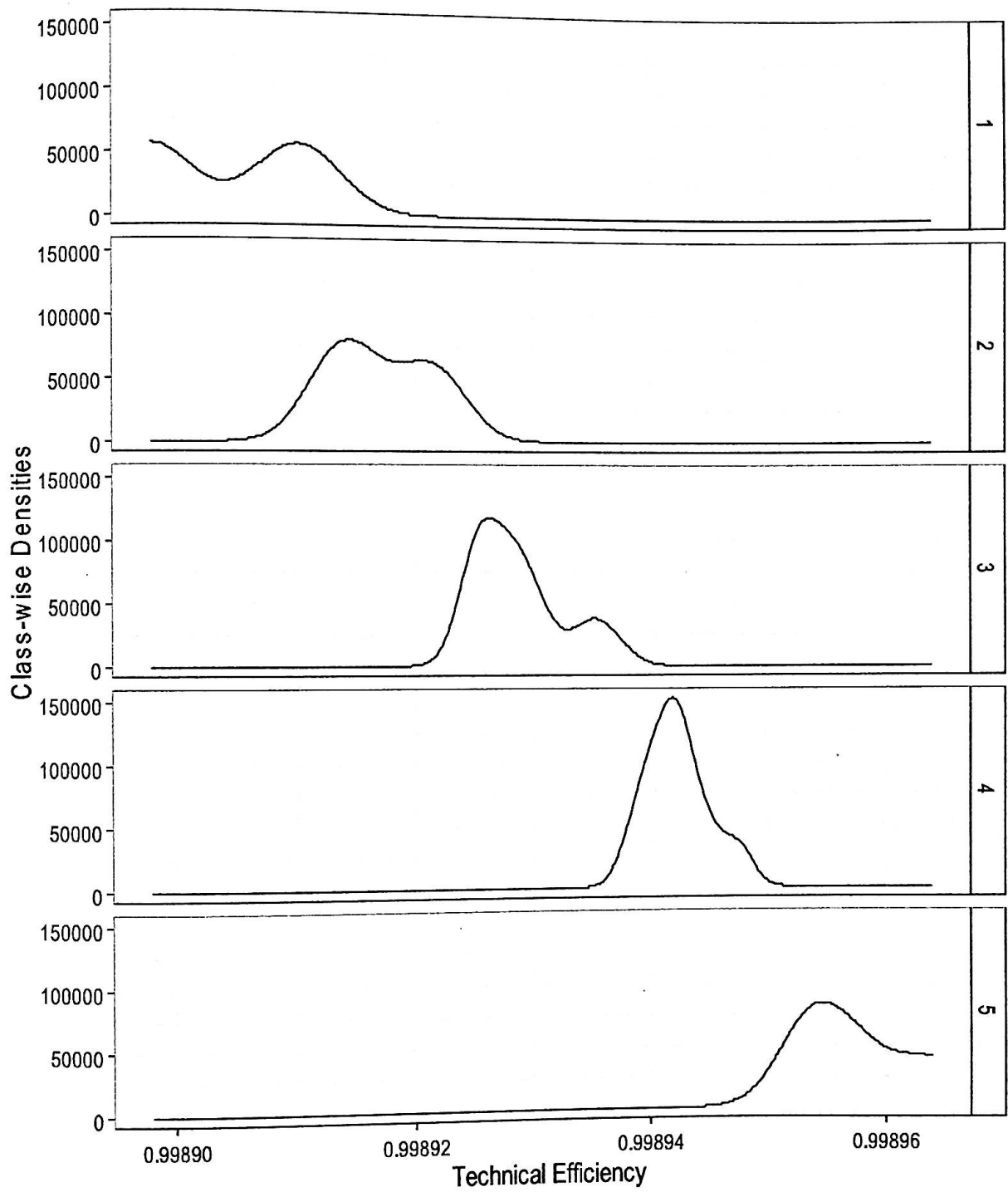


Figure 5.12: Stage wise estimated TE of Boro farmers of Hamimpur
(Source: Author's surveyed data)

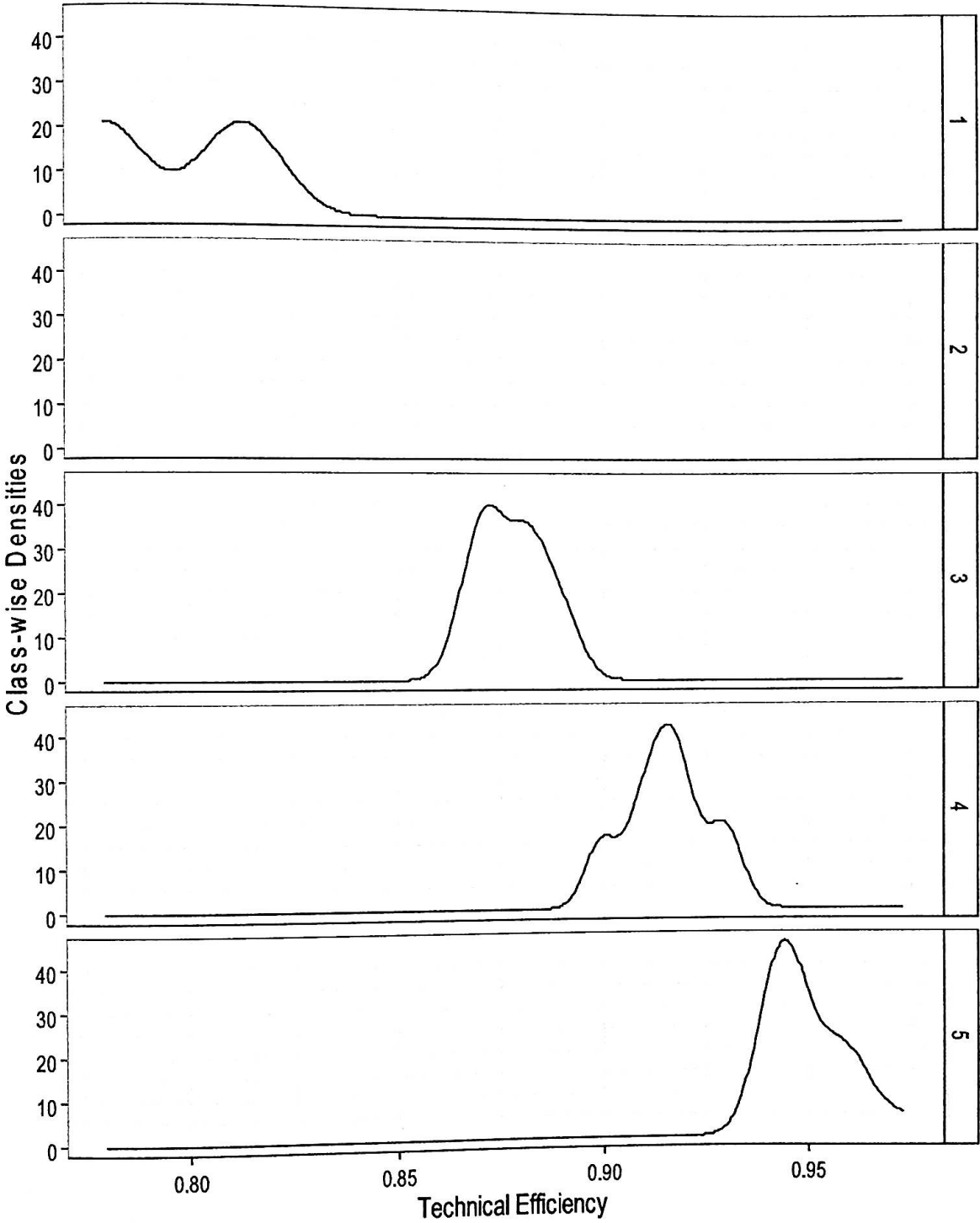


Figure 5.13: Stage wise estimated TE of Boro farmers of Kahaloo

(Source: Author's surveyed data)

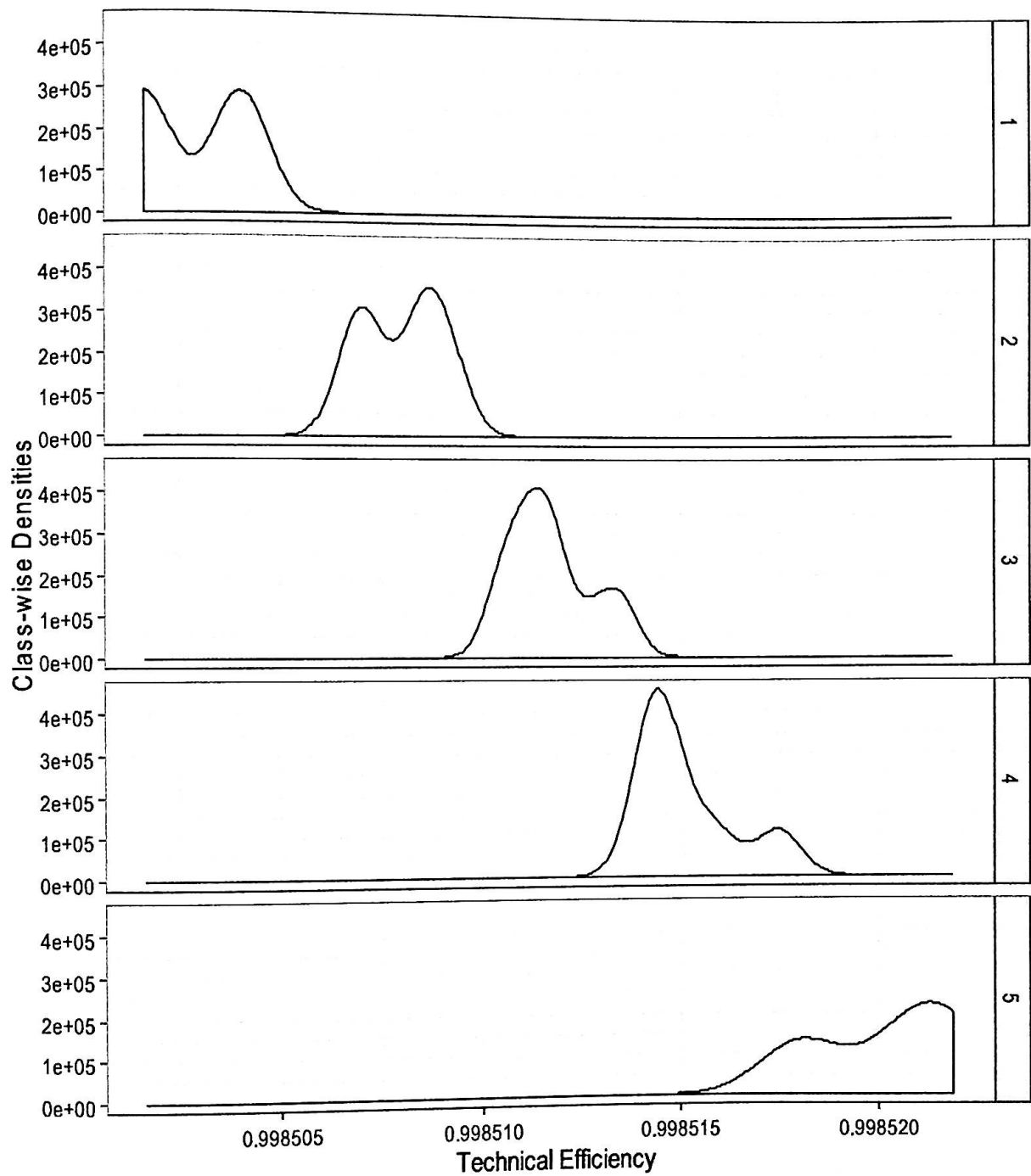


Figure 5.14: Stage wise estimated TE of Boro farmers of Sonatala

(Source: Author's surveyed data)

It is evident for Figure 5.7 that the technical efficiencies of five groups are limited to about 0.750 to 0.974 and the no densities are found in the second group. The class case-wise densities show no normalities for Singra Upazila. However, for Baraigram, all the class case-wises possesses the densities of non-normal pattern having three modal classes in the class II. The Kaunia Upazila, estimated densities found as zero for the class of case-I having the range of TE from 0.839 to 0.985. The range of estimated densities for Mithapukur is 0.497- 0.939. The Hakimpur Upazila shows densities in all the classes with the range of 0.998- 0.999 noted from Figure 5.12. On the other hand, for Kahaloo, all the class case-wises possesses the densities of non-normal pattern having no densities in the class II have marked from Figure 5.13. However estimated densities against TE of Boro farmers of Sonatala Upazila of Bogura showing in all the five stages with an indication of high values near clustered around unity is marked from the Figure 5.14.

CHAPTER VI

FARMERS' PERFORMANCE INDICATORS

FARMERS' PERFORMANCE INDICATORS

6.1. Introduction

As we are dealing with the firm-level data of Boro producers of the Northern region of Bangladesh, it is essential to investigate the integrated management of the farmers in the efficiency ground. As such, the technical efficiency/inefficiency of such systems has been used as the statistical tools with the help of the researcher surveyed data. The indicators of the farmers' performances have been addressed in this chapter and it has been measured in different aspects of production efficiencies with the help of SFA modeling. Discussion of empirical results followed by the contributory variables on TE, Inefficiency indicators and Contributory Variables Influencing Inefficiency have been employed in this chapter.

6.2. Efficiency of the empirical models

As because the stochastic behavior of models make it relatively less risk of infecting by outliers than deterministic frontier models, the production frontier have been analyzed to specify the output of the SFA for a set of given inputs variables (Aigner *et al.*, 1977 and Meeusen and van den Broeck, 1977) in this study. In the SFA the error term ε , are separated into random error and the random variables explanatory of inefficiency effects makes more reliable the analyzed results with a suitable functional form of the frontier model. As a traditional convention, widely used from the CD production function have been used in this with the help of the researcher collected data of individual farmers for four selected districts of the Northern region of Bangladesh as stated in the section 4.3 of chapter IV. In the light of selected literature matching with our objectives two steps analysis has been done. In the first step, the SFA function models have been fitted under the Half-Normal assumption of errors and capture the technical efficiency of farmers, and following

these, the inefficiency effects have been tried to pick up as causal factors influential to the efficiencies (Pitt and Lee, 1981; Kalirajan, 1982; Parikh and Shah, 1994). District-wise Maximum Likelihood Estimators (MLE) with their test statistics values are discussed successively followed by the results of pooled data of the study region.

6.2.1 Stochastic frontier estimators and their contributions

The estimators of parameters using Cobb-Douglas (CD) stochastic frontier production function under the Half-Normal assumption in Rangpur district is presented in Table 6.1.

Table 6.1: SFA estimators of farmers in Rangpur district.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	1.614	0.134	12.045	0.000
Labor	0.008	0.006	1.274	0.203
Harv	0.022	0.028	0.785	0.433
Pest	0.048	0.034	1.426	0.154
Seed	0.077	0.065	1.185	0.236
Fert	0.636	0.071	8.970	0.000
Land	0.018	0.004	4.335	0.000
Variance parameters				
Sigma Square	0.007	0.002	3.052	0.002
Gamma	0.769	0.191	4.030	0.000
Log likelihood	116.616			
Mean TE	0.94			
<i>n</i>	84			

(Source: Author's surveyed data)

Among the six variables only two variables fertilizer and land were found significantly positive while the remaining four variables labour, harvesting, pesticide and seed have noticed as positive but insignificant impact. This implies that fertilizer and land are the important variables in increasing the productivity of Boro rice in Rangpur district. Furthermore, the diagnostic statistics of inefficiency component reveals that the variance parameter sigma squared (σ^2) is found to be positive and statistically significant at 1%, which indicates a good fit of the model and the correctness of the specified distributional assumptions. The estimated variance ratio parameter gamma (γ) of 0.769 and also statistically significant at 1% level, indicating that 77% of the difference between the observed and frontier output was primarily due to the factors under the control of the farmers. The average level of technical efficiency has been estimated as 94% for farms as a whole, implying that on an average the sample farmers tend to realize around 94% of their technical abilities. Hence, on an average, approximately only 6% of the technical potentials were not realized. Therefore, it is possible to improve the yield by 6% by following efficient crop management practices without increasing the level of inputs application. Table 6.2 presents the results of the ML estimation of SFA under the Half-Normal distributional assumption for Boro production of Dinajpur district.

Table 6.2: SFA estimators of farmers in Dinajpur district.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	2.254	0.174	12.932	0.000
Labor	0.086	0.028	3.127	0.002
Harv	0.031	0.050	0.619	0.536
Pest	-0.063	0.016	-3.940	0.000
Seed	-0.019	0.067	-0.286	0.775
Fert	0.416	0.058	7.128	0.000
Land	0.550	0.092	6.006	0.000
Variance parameter				
Sigma Square	0.002	0.001	4.201	0.000
Gamma	0.922	0.066	13.952	0.000
Log likelihood	169.287			
Mean TE	0.96			
<i>n</i>	80			

(Source: Author's surveyed data)

The estimators of CD production frontier shows that the estimated coefficients for labor, fertilizer, land and pesticide are significant at 1% level may be considered as the determinants of Boro rice output in Dinajpur district. Among the significant variables labor, fertilizer and land have found to be positively related to the output of Boro rice but pesticide have a negative significant impact on the output. It may be due to improper or over utilization of pesticide. Besides, positive coefficient value of harvesting and negative coefficient value of seed are not significant, implying that these variables have no effect on Boro rice output of Dinajpur. The diagnostics of inefficiency component reveals that sigma squared (σ^2) was positive and statistically significant at 1%, which indicates goodness of fit, and the correctness of the distributional form assumed for the composite error term. Another important result in the analysis is the variance ratio parameter gamma (γ) which found to be significant at 1% level expressing that about 92% of Boro rice output deviations are caused by differences in farm level technical efficiency as opposed to the random variability that are outside their control of the producers. The mean technical efficiency was 0.96 in Boro farming which indicates that the selected farms remained near the frontier and there is less scope to further increase the productivity at the existing technology. There are 88 farmers have selected from Natore district and the SFA estimators are estimated and enlisted in Table 6.3.

Table 6.3: SFA estimators of farmers in Natore district.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	1.371	0.103	13.263	0.000
Labor	0.223	0.040	5.559	0.000
Harv	0.070	0.048	1.447	0.148
Pest	0.427	0.051	8.395	0.000
Seed	0.201	0.041	4.900	0.000
Fert	-0.016	0.050	-0.312	0.755
Land	0.006	0.002	2.411	0.010
Variance parameter				
Sigma Square	0.008	0.002	4.178	0.000
Gamma	0.899	0.077	11.656	0.000
Log likelihood	130.128			
Mean TE	0.938			
<i>n</i>	88			

(Source: Author's surveyed data)

The results revealed in Table 6.3 shows that Harv and Fert are insignificant while all other estimates including constant are significant at 1% level. The coefficients for labor, pesticide, seed and land are positive which confirm that, there is a positive relationship between these inputs and the output of Boro rice. Pesticide had the biggest positive elasticity (0.427), which was strongly significant at 1% level. This implies that 1% increase in pesticide quantity significantly increased Boro rice output by 0.42%. This indicated that the Natore district is one of the most diseases and pest affected areas in Boro farming. In addition labor, seed and land influenced Boro rice output at 1% significance level and the estimated coefficients were 0.223, 0.204 and 0.006. As such, a 1% increase in each variable in Boro rice production significantly increased output by 0.223%, 0.204% and 0.006% respectively. Other insignificant determinants of productivity included the fertilizers and harvesting cost. The estimated sigma square is significantly different from zero. This indicates goodness of fit and the correctness of the specified distribution assumption of the composite error term. Indeed, the value of gamma (γ) was 0.899, which shows that about 90% of variations of Boro rice output from the frontier were attributed to technical inefficiencies of the producers.

The farmers in Bogura district are very much engage with Boro production. According to the sampling design there are 98 farmers are conceded in this study and the ML estimates of CD production function is presented in Table 6.4.

Table 6.4: SFA estimates of farmers in Bogura district.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	2.230	0.298	7.487	0.000
Labor	0.096	0.066	1.454	0.146
Harv	0.052	0.030	1.695	0.090
Pest	-0.120	0.047	-2.547	0.011
Seed	0.123	0.159	0.777	0.437
Fert	0.416	0.099	4.184	0.000
Land	0.266	0.178	1.500	0.134
Variance parameter				
Sigma Square	0.014	0.002	6.749	0.000
gamma	0.000	0.017	0.001	0.999
Log Likelihood	68.590			
Mean TE	1.000			
<i>n</i>	98			

(Source: Author's surveyed data)

As shown in Table 6.4, all the variables except Pest have positive interactions with output and the variables Harv, Pest, Fert are significant at 1% level. The use of these inputs indicates potential of increasing the level of production through raising their usage. The Seed and Labor are found as insignificant. However, the effect of Pesticide was found significant negative which indicates it's over or improper use in production of Boro rice. Additionally, the results show the value of 0.014 for sigma squared (σ^2) which is different from zero at 1%, indicating a good fit and correctness of specified distributional assumption of the composite error term. The parameter gamma (γ) is insignificant and the mean technical efficiency is approximately equals to unity.

6.2.2. Stochastic frontier estimators of pooled data

There are the inherent limitations of individual grouping in any statistical computations so far the effect of individual districts have been judged in this study may raise questions have been about the appropriateness of recommending SFA models. As such, SFA models of CD production function have been used with the help of the researcher collected data of 350 individual farmers of four selected districts of the Northern region of Bangladesh. The MLE estimators of the model (4.3 and 5.2) under the Half-Normal assumption of errors is given in Table 6.5.

Table 6.5: SFA estimates of pooled data with half-normal assumption.

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	1.700	0.063	27.132	0.000
Labor	0.013	0.007	1.906	0.057
Harv	0.034	0.017	1.978	0.048
Pest	0.037	0.020	1.840	0.066
Seed	0.235	0.041	5.701	0.000
Fert	0.543	0.042	12.882	0.000
Land	0.007	0.002	3.993	0.000
Variance parameters				
Sigma Square	0.020	0.003	7.972	0.000
Gamma	0.710	0.072	9.897	0.000
Log Likelihood	296.992			
Mean TE	0.914			
<i>n</i>	350			

(Source: Author's surveyed data)

All of the estimated coefficients of the model had a positive impact on output and they were all statistically significant. The estimated coefficient of labor is 0.013 with its z value of 1.906. The variables harvesting, pesticide, seed, fertilizer, and land were found as 0.034, 0.037, 0.235, 0.543, and 0.007 respectively. As therefore, all the independent variables contribute to increasing the production of Boro rice in the study region.

The inefficiency component reveals can be measured by justifying the null hypothesis of the goodness of fit of using the inefficiency model by sigma squared statistics. The likelihood chi-square for variance parameter based is 6.667 and that is significant in comparing with the critical value. This supports the rejection of the null hypothesis. That is inefficiency is a significant portion of the total error, and SFA is appropriate for the analysis. The mean TE of Boro farmers is recorded as 0.914 indicating that the farmers in the study area realized their technical abilities and the remaining 9 percent of farmers are operating below the production frontier. This 9 percent of output loss may be due to the inefficiency in the Boro farming system or due to the inefficiencies among the sample farmers or both. A value of γ tending to unity indicates the appropriateness of using the efficiency model. The score is measured as 0.710 for the pooled sample indicates the presence of a significant effect of inefficient variables in the model. In other words, it is justified to use the inefficiency model for Boro production. It is noted that about 71 percent of differences between the observed and maximum production frontier outputs were mainly due to input variables of resources. As such, rest only 29 percent are due to random factors outside the control variables that may be identified by the inefficiency model could be a decision-making parameter causing the individual farmers of the research area. As therefore, it is evident from the result that variables Labor, Harv, Pest, Seed, Fert, and Land affect the farm level activities as well as the technical efficiency of the farmers of the study area.

6.3. Firm level impact of loan

According to Ghorbani (1997) getting credit with low interest rate to farmers may be supportive against risk for development of policies and welfare. The credit access (receiving Loan) may help to Boro producers for the management of their insecurity due to the economic condition. Financing in Agriculture is one of the most important issues persuading the output. It can help to eliminate the financial constraints to invest in farm activities through increasing productivity and improving technologies for the marginal level farmers. The SFA modelling of firm level Boro producers of four northern districts have performed on Loan receiving or non-receiving aspects. The estimated output of SFA models are enlisted from Table 6.6 - Table 6.9.

Table 6.6: SFA estimates of loan category of Rangpur district.

Variable	Receiving Loan				Not Receiving Loan			
	Estimate	SE	z value	Pr(> z)	Estimate	SE	z value	Pr(> z)
Intercept	1.657	0.362	4.571	0.000	1.554	0.173	9.000	0.000
Labor	0.006	0.007	0.973	0.331	0.010	0.008	1.330	0.182
Harv	-0.003	0.041	-0.080	0.936	0.009	0.033	0.260	0.797
Pest	0.137	0.041	3.374	0.001	0.036	0.039	0.910	0.364
Seed	0.159	0.152	1.041	0.298	0.080	0.075	1.050	0.292
Fert	0.502	0.183	2.742	0.006	0.688	0.078	8.860	0.000
Land	0.012	0.009	1.411	0.158	0.018	0.005	3.570	0.000
Variance parameters								
Sigma Square	0.002	0.000	3.231	0.001	0.006	0.003	1.905	0.057
Gamma	0.99	0.001	831.581	0.000	0.543	0.488	1.111	0.266
Log Likelihood	44.117				88.879			
Mean TE	0.960				0.955			
<i>n</i>	18				66			

(Source: Author's surveyed data)

Table 6.7: SFA estimates of loan category of Dinajpur district.

Variable	Receiving Loan				Not Receiving Loan			
	Estimate	SE	z value	Pr(> z)	Estimate	SE	z value	Pr(> z)
Intercept	2.313	0.235	9.830	0.000	2.356	0.261	9.040	0.000
Labor	0.087	0.027	3.250	0.001	0.277	0.083	3.340	0.001
Harv	0.072	0.084	0.860	0.389	-0.218	0.106	-2.060	0.040
Pest	-0.054	0.020	-2.770	0.006	-0.037	0.026	-1.410	0.160
Seed	-0.099	0.083	-1.180	0.236	0.029	0.130	0.220	0.824
Fert	0.337	0.079	4.270	0.000	0.624	0.111	5.630	0.000
Land	0.647	0.109	5.960	0.000	0.334	0.106	3.160	0.002
Variance parameters								
Sigma Square	0.003	0.001	3.896	0.000	0.006	0.003	1.993	0.046
Gamma	0.956	0.049	19.431	0.000	0.702	0.399	1.760	0.078
Log Likelihood	120.915				57.002			
Mean TE	0.961				0.983			
<i>n</i>	58				22			

(Source: Author's surveyed data)

Table 6.8: SFA estimates of loan category of Natore district.

Variable	Receiving Loan				Not Receiving Loan			
	Estimate	SE	z value	Pr(> z)	Estimate	SE	z value	Pr(> z)
Intercept	1.670	0.126	13.193	0.000	1.132	0.313	3.620	0.000
Labor	0.355	0.055	6.446	0.000	0.179	0.053	3.380	0.001
Harv	0.014	0.022	0.621	0.535	0.186	0.159	1.180	0.240
Pest	0.040	0.056	0.724	0.469	0.416	0.091	4.560	0.000
Seed	0.161	0.032	4.994	0.000	0.208	0.077	2.700	0.007
Fert	0.383	0.060	6.350	0.000	-0.052	0.062	0.840	0.399
Land	0.002	0.002	1.302	0.193	0.003	0.011	0.240	0.808
Variance parameters								
Sigma Square	0.001	0.004	4.030	0.000	0.013	0.006	2.285	0.022
Gamma	0.000	0.037	0.001	0.999	0.971	0.101	9.610	0.000
Log Likelihood	87.155				70.575			
Mean TE	0.998				0.917			
<i>n</i>	35				53			

(Source: Author's surveyed data)

Table 6.9: SFA estimates of loan category of Bogura district.

Variable	Receiving Loan				Not Receiving Loan			
	Estimate	SE	z value	Pr(> z)	Estimate	SE	z value	Pr(> z)
Intercept	2.173	0.355	6.120	0.000	0.167	0.415	0.403	0.687
Labor	0.095	0.072	1.330	0.183	0.444	0.533	0.834	0.404
Harv	0.051	0.033	1.530	0.126	-0.334	0.079	-4.219	0.000
Pest	-0.127	0.050	-2.520	0.012	0.775	0.157	4.925	0.000
Seed	0.194	0.200	0.970	0.331	-0.187	0.096	-1.958	0.050
Fert	0.430	0.108	3.990	0.000	0.879	0.180	4.882	0.000
Land	0.191	0.224	0.850	0.394	-0.369	0.151	-2.444	0.015
Variance parameters								
Sigma Square	0.016	0.003	6.328	0.000	0.002	0.001	2.059	0.039
Gamma	0.000	0.011	0.001	0.999	0.999	0.009	114.898	0.000
Log Likelihood	54.878				33.015			
Mean TE	0.998				0.968			
<i>n</i>	84				14			

(Source: Author's surveyed data)

Harvest, Pest and Land are insignificant for Loan (Yes) group but for Non-Loan receiving group Harv, Fert and Land are insignificant. Although Gamma is significant for non-receiving Loan group while it was found to be insignificant for Loan receiving group and the mean efficiency decreases in compare to the Loan receiving group of Natore.

Labor and Land are insignificant for Loan (Yes) group but for non-receiving Loan group only Labour is insignificant for Bogura. Similar results for Gamma and the mean efficiency are noted here.

For Loan (Yes) group Labor, Harv, Seed and Land but for non-receiving Loan group Labor, Harv, Pest and Seed are insignificant. Although Gamma is significant for Loan receiving group, it is in significant for non-receiving group of Rangpur. The mean efficiency also decreases here.

For Loan (Yes) group Harv but for non-receiving Loan group Pest and Seed are insignificant. Although Gamma is significant for Loan receiving group, it is in significant for non-receiving group of Dinajpur. The mean efficiency also decreases here.

6.4. Inefficiency indicators of farmers

Battese and Coelli (1995) was the pioneer in analyzing the empirical SFA model to determinate the technical efficiency in the agricultural. They assumed the combined estimation of the model comprises both the efficient frontier of agricultural production and the influential variables for the inefficiency of production in the agricultural area of interest of firm level agricultural. The usefulness of the SFA model in justifying the inefficiency impacts following the reference of Coelli and Battese (1996) others (Tian and Wan (2000); Villano and Fleming (2006)) have been justified for the selected data sets under the objectives of the study.

The estimators of the inefficiency models of Boro producers have completed and are provided in the Table 6.10 - Table 6.13.

Table 6.10: Inefficiency estimators of Rangpur district

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	1.709	0.127	13.467	0.000
Labor	0.007	0.006	1.177	0.239
Harv	0.018	0.026	0.700	0.484
Pest	0.032	0.030	1.065	0.287
Seed	0.128	0.064	1.998	0.046
Fert	0.586	0.067	8.773	0.000
Land	0.019	0.004	4.633	0.000
Inefficiency variables				
Age	-0.710	2.885	-0.246	0.806
Fmem	-0.962	5.794	-0.166	0.868
Fexp	0.791	3.252	0.243	0.808
Variance parameter				
Sigma Square	0.581	2.737	0.212	0.832
Gamma	0.996	0.019	51.535	0.000
Log likelihood	118.004			
Mean TE	0.96			
<i>n</i>	84			

(Source: Author's surveyed data)

The fit of the model and the correctness of the specified distributional assumptions are confirmed by the estimated variance parameter sigma square ($\sigma^2 = 0.581$) following the hypothesis that the stochastic frontier production is significantly different from zero. The estimated variance ratio parameter gamma (γ) of 0.996 and statistically significant at 1% level meant that 99.9% of the total variation in Boro rice output is due to technical inefficiency.

The result revealed that the estimated coefficients of Fertilizer, Land and seed were positive and significant at 1% and 5% level and hence play a vital role in Boro rice production in Rangpur district. The estimated coefficients for Fertilizer and Land were 0.586 and 0.019 which are positive and statistically significant at 1% level. Another vital estimated coefficient for Seed was 0.128 that is also positive and statistically significant at 5% level. It means that 1% increase in Fertilizer cost, Land and Seed cost will lead to increase in Boro rice production by of 0.586%, 0.019% and 0.128% respectively. On the other hand, the estimate of Labor cost, Harvesting cost and Pesticide cost were positive, but not significant, therefore, had no significant influence on Boro rice output.

The average technical efficiency for the farmers for the inefficiency model is 0.96 implying that, on the average the variables are able to explain 96% of potential output from a given mixture of production inputs. Thus, in a short run, there is minimal scores 4% of increasing the efficiency, by adopting the technology and techniques used by the best Boro rice farmer.

The estimated result of the inefficiency model is contained in lower part of Table 1. The results show that Age and Family size have a negative sign, and therefore reduce technical inefficiency (or increase technical efficiency) while surprisingly farming experience have marked no such contribution like other two.

Table 6.11: Inefficiency estimators of Dinajpur district

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	2.236	0.162	13.810	0.000
Labor	0.080	0.027	2.941	0.003
Harv	0.014	0.049	0.291	0.771
Pest	-0.077	0.016	-4.808	0.000
Seed	-0.001	0.054	-0.026	0.980
Fert	0.466	0.056	8.312	0.000
Land	0.518	0.076	6.827	0.000
Inefficiency variables				
Age	-5.203	14.835	-0.351	0.726
Fmem	-3.897	10.742	-0.363	0.717
Fexp	3.065	8.807	0.348	0.728
Variance parameter				
Sigma Square	3.703	10.489	0.353	0.724
Gamma	1.000	0.000	3601.878	0.000
Log likelihood	171.147			
Mean TE	0.97			
<i>n</i>	80			

(Source: Author's surveyed data)

With reference to Table 6.11, the high value of variance parameter sigma square ($\sigma^2 = 3.703$) which indicates the goodness of fit of the specified distributional assumptions of the composite error was observed to be positive. Its positivity indicated that the distributional assumption of the composite error was of good fit. The estimated gamma value (γ) was 0.999 and statistically significant at 1%, indicating that 99.9% of the total deviation from the efficient Boro rice frontier output is due to inefficiencies arising from the production process while the random effects constitute 0.1%. This further means that technical inefficiency effects dominate the noise effect in explaining the total variation in Boro rice output.

Results revealed that Labor cost, fertilizer cost and Land under Boro rice were positively affecting Boro yield and were found statistically significant at 1% level. The coefficient of Pesticide cost was also statistically significant at 1% level of significance with negative coefficient. Therefore the increment of the variables such as, Labor, fertilizer and Land under Boro rice by 1% will increase output by 0.080%, 0.466%, and 0.518% respectively. On the other hand, the estimated coefficient of pesticide was -0.077. This shows that 1% of the additional amount of pesticide would cause a decrease in Boro rice yield by 0.077%. However, positive value of Harvesting cost and negative value of Seed cost are statistically insignificant. This suggests that Seed and harvesting cost do not affect the yield of Boro rice.

Although the inefficiency variables Age and Family size have a negative sign Farming experience has the positive sign. Thus, reductions of technical inefficiency are caused by the first two variables while the last one are seen to have no such similarities with previous two variables.

The mean technical efficiency of the model of Dinajpur district is 97% indicates that the average Boro rice farmer in the area produces about 97% of the potential output given the existing technology available. Thus, about 3% of output was lost due to inefficiency.

Table 6.12: Inefficiency estimators of Bogura district

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	2.250	0.229	9.808	0.000
Labor	0.081	0.067	1.213	0.225
Harv	0.043	0.029	1.444	0.149
Pest	-0.111	0.039	-2.851	0.004
Seed	0.125	0.157	0.798	0.425
Fert	0.420	0.096	4.400	0.000
Land	0.281	0.173	1.624	0.104
Inefficiency variables				
Age	-0.001	0.000	-2.430	0.015
Fmem	0.023	0.008	2.714	0.007
Fexp	-0.004	0.001	-2.760	0.006
Variance parameter				
Sigma Square	0.014	0.002	7.389	0.000
Gamma	0.000	0.000	1.453	0.146
Log likelihood	70.177			
Mean TE	0.98			
<i>n</i>	98			

(Source: Author's surveyed data)

It is seen from Table 6.12 that the variable fertilizer is positively affecting Boro rice yield and also found statistically significant at 1% level with the value of 0.420, which implies that, an increase in the fertilizer cost would significantly lead to increased Boro yield or 1% increase in fertilizer cost will lead to increase in Boro yield by 0.42%. The pesticide variable is found to have a significant negative effect on Boro rice production with the elasticity of -0.111. This figure shows that 1% of the additional amount of pesticide would cause a decrease in Boro rice production by 0.111%. This negative effect may be caused by the inappropriate use of pesticide by the farmers that lead to ineffective application. The value of sigma square (σ^2) was 0.014 and was statistically significant at 1% level. This indicates a good fit and correctness of the specified distributional assumptions of the composite error terms while the gamma (γ) which is the proportion of deviation from frontier that is due to inefficiency estimate was zero.

A zero value of γ indicates that the gap between actual output and the maximum possible output mainly comes from other uncontrolled pure random factors, which makes the use of stochastic frontier model meaningless and, in this case, the ordinary least squares (OLS) estimates of the model are equivalent to the MLE results.

The mean technical efficiency (TE) was found to be 98%. In other words, on average Boro rice producer in the district incur only 2% loss in output due to technical inefficiency. This implies that on average output can be increased by at least 2% while utilizing existing resources and technology if inefficiency factors are fully addressed or more precisely, on the average, output can be expanded by as much as 2% if appropriate measures are taken to improve technical efficiency.

The results of the inefficiency model shows that, all variables used in the analysis, Age, Family size and Farming experience were significantly contributing to technical inefficiency of Boro rice farmers in Bogura district.

The estimated coefficient for age variable in the inefficiency model was negative (-0.001) and statistically significant at 1% as was expected, implying that the older farmers were more productive than the younger ones. The estimated coefficient of farming experience (-0.004) is negative, conforming to a priori expectation and it is statistically significant at the 1% level. The implication is that farmers with more experience in rice production are more efficient than the inexperienced ones in the area.

The estimated coefficient of family size (0.023) was positive and statistically significant at 1% level, meaning that farmers with large family size will be more technically inefficient, also as the family size increases it will obviously decreases their production efficiency, This may be due to the reason that family with large number members may not be able to use appropriate input combinations due to shortage of cash.

Table 6.13: Inefficiency estimators of Natore district

Variable	Estimate	Std. Error	z value	Pr(> z)
Intercept	1.400	0.092	15.313	0.000
Labor	0.213	0.036	5.869	0.000
Harv	0.029	0.038	0.763	0.445
Pest	0.334	0.049	6.874	0.000
Seed	0.255	0.036	6.999	0.000
Fert	0.134	0.054	2.476	0.013
Land	0.002	0.002	1.053	0.292
Inefficiency variables				
Age	13.700	30.500	-0.449	0.653
Fmem	23.400	52.100	0.450	0.652
Fexp	6.550	14.600	0.450	0.653
Variance parameter				
Sigma Square	14.700	32.800	0.449	0.654
Gamma	0.99	0.000	6122.760	0.000
Log likelihood	138.894			
Mean TE	0.95			
<i>n</i>	88			

(Source: Author's surveyed data)

It is depicted from the Table 6.13 that the value of the sigma square (σ^2) is large enough and significantly different from zero. This indicates goodness of fit as well as correctness of the distributional form assumed for the composite error term. Also, the high value of gamma (γ) = 0.990 indicates that the influences that were unexplained by the production function are the main sources of random error. It is significant at one percent level and indicates that 99% of the variation in farmer's output is a consequence of technical inefficiency in the district. Thus, the presence of one-sided error component in the model is confirmed and the average production function (Ordinary Least Square, OLS) is inadequate in representing the data.

The results in Table 1 above indicate that Labor, Pesticide, Seed and Fertilizer contribute positively and significantly to the output of Boro rice at 1% level, which implies that these variables affect the yield of the Boro rice significantly in Natore district. To obtain more output of Boro rice; equivalent to the value of their coefficients would be obtained from using 1% additional unit of these production variables. However, remaining variables such as Harvesting cost and Land under Boro rice contribute also positively but not significantly implying that Harvesting cost and Land variables do not affect the yield of the Boro rice significantly in the district.

The inefficiency determinants such as Age, Family size and Farming experience with positive signs are not statistically significant that can be unable to describe the model significantly due to insignificant levels of the statistics.

The predicted mean technical efficiency for Boro rice farmers of Natore district was 0.95. This implies that the output could be increased by 5% if all Boro rice farmers could achieve technical efficiency at the same level of the best farmer in the study area.

6.4.1. Inefficiencies and test of hypothesis

Technical inefficiency is also important in analysing the SFA models. As therefore in this study the author is interested to test the inefficiency parameters for the full data set of selected districts. Since Credit or Loan receiving characteristics is one more important points for the farmers the data have been categorized according to the Loan receiving category and tested herewith. The Log Likelihood and test statistics for Loan category of the following hypothesises are presented in the Table 6.14.

$$H_{10}:\gamma=\delta_0=\delta_{Age}=\delta_{Fmem}=\delta_{Fexp}=0$$

$$H_{20}:\gamma=\delta_0=\delta_{Age}=\delta_{Fexp}=0$$

Table 6.14: Likelihood and chi-square statistics of districts by loan

Location	Hypothesis	Loan Receiving Group			Loan Non-Receiving Group		
		Log likelihood	Test Statistic	Decision	Log likelihood	Test Statistic	Decision
Natore	H_{10}	87.495	0.680	Accepted	71.484	4.110	Accepted
	H_{20}	87.170	0.029	Accepted	72.540	6.223	Rejected
Bogura	H_{10}	56.696	3.6362	Accepted	32.976	6.0757	Accepted
	H_{20}	55.649	1.5431	Accepted	32.824	5.7717	Accepted
Rangpur	H_{10}	45.272	8.520	Rejected	93.109	8.646	Rejected
	H_{20}	44.957	7.891	Rejected	92.923	8.274	Rejected
Dinajpur	H_{10}	93.109	8.647	Rejected	62.302	10.697	Rejected
	H_{20}	92.923	8.274	Rejected	59.600	5.292	Rejected

(Source: Author’s surveyed data)

The null hypotheses H_{10} of Loan receiving and no-receiving groups for Natore and Bogura are insignificant but this hypothesis for Rangpur and Dinajpur are rejected at 5% level of significance. The null hypothesis H_{20} is that the explanatory inefficiency variables Age and Farming experience in the model are simultaneously equal to zero. The LR test is used to compute the test statistic using the logarithmic likelihood value of stochastic frontier model without explanatory variables of inefficiency effect model (H_0) and the full frontier model with selected two explanatory variables of inefficiency effect model (H_1). The computed χ^2 values of Natore, Bogura, Rangpur and Dinajpur are 6.223, 5.771, 8.274 and 5.292 respectively at 5% significance level for Non-Loan receiving group. It was found as 0.029, 1.5431, 7.891, and 8.274 respectively at 5% significance level for Loan receiving group accordingly. Therefore, the explanatory variables associated with inefficiency model are jointly different from zero for Rangpur and Dinajpur are rejected but the effect was identified to zero for Natore and Bogura because of their extracted technical efficiency effect equals to unity.

The district wise Log Likelihood and test statistics are presented in the Table 6.15.

Table 6.15: Likelihood and chi-square statistics of districts

Null Hypothesis (H_0)	Log Likelihood	Test Statistic	Conclusion
Natore district			
$H_{10} : \gamma = \delta_0 = \delta_{Age} = \delta_{Fmem} = \delta_{Fexp} = 0$	138.890	21.991	Rejected
$H_{20} : \gamma = \delta_0 = \delta_{Age} = \delta_{Fexp} = 0$	137.590	19.394	Rejected
Bogura district			
$H_{10} : \gamma = \delta_0 = \delta_{Age} = \delta_{Fmem} = \delta_{Fexp} = 0$	70.177	3.173	Accepted
$H_{20} : \gamma = \delta_0 = \delta_{Age} = \delta_{Fexp} = 0$	69.141	1.102	Accepted

Contd....

Rangpur district			
$H_{10} : \gamma = \delta_0 = \delta_{Age} = \delta_{Fmem} = \delta_{Fexp} = 0$	118.00	4.640	Accepted
$H_{20} : \gamma = \delta_0 = \delta_{Age} = \delta_{Fexp} = 0$	117.850	4.327	Accepted
Dinajpur district			
$H_{10} : \gamma = \delta_0 = \delta_{Age} = \delta_{Fmem} = \delta_{Fexp} = 0$	171.150	13.253	Rejected
$H_{20} : \gamma = \delta_0 = \delta_{Age} = \delta_{Fexp} = 0$	171.080	13.127	Rejected

(Source: Author's surveyed data)

The inefficiency variables included in this study are tested using two null hypothesis H_{10} and H_{20} of full data for the districts. In the first hypothesis, the simultaneously effect of explanatory inefficiency variables Age and Farming experience and Family Members in the model are equal to zero. The LR test is used to compute the test statistic using the logarithmic likelihood value of stochastic frontier model without explanatory variables of inefficiency effect model (H_0) and the full frontier model with selected explanatory variables of inefficiency effect model (H_1).

The computed χ^2 values of H_{10} for the districts Natore, Bogura, Rangpur and Dinajpur 21.991, 3.173, 4.640 and 13.253 respectively indicating that Natore and Dinajpur are significant at 5% significance level but Bogura and Rangpur are insignificant at the same level of significance. The χ^2 values of H_{20} for the districts Natore, Bogura, Rangpur and Dinajpur are 19.394, 1.102, 4.327, and 13.127 respectively. Similarly, the districts Natore and Dinajpur are found to be significant at 5% significance level while Bogura and Rangpur are found to be insignificant at the same level of significance. As because the mean technical efficiency of these two districts is approximately equals to unity, the joint impact of the inefficiency variables are identified as zero.

significance indicating Age and Fmem have contributory impact on the inefficiency model. Similarly independent impact of variables Age, Fmem and Fexp and Loan are seen in the model.

6.5. JLMS efficiency scores

In the classic and cross-sectional stochastic frontier models, the inefficiencies are considered as random and no such explanation of the presence of concomitant observable features of the firm is noticed. Although some references (Caudill and Ford, 1993; Caudill *et al.*, 1995 and Hadri, 1999) are seen to be motivated by the probable presence of heteroscedasticity in the error term where such authors were recast their models to separate the direct impact of exogenous determinants of inefficiency for the individual units (firm). Thus, it is a question of how any extreme inefficiency can be transformed into a more realistic form of observables. Therefore, search for the possible determinants may pertain to the relationship of them with inefficiency (Kumbhakar *et al.*, 1991; Huang and Liu, 1994 and Battese and Coelli, 1995). In this circumstance, a two-step method was advised to model the influence of specific covariates on firm-level inefficiency by Reifschneider and Stevenson (1991). However, Wang and Schmidt (2002) pointed out that if input and indicator variables are correlated then the first step of the two-step procedure suffers from omitted variable bias. The modified JLMS estimator defined by Greene (2005) in estimating the technical efficiencies of the firms and it can be observed as representing the mean of the conditional distribution where both the errors (u_i and e_i) are drawn under repeated sampling and are considered as inconsistent but both estimators would not be equal the deep parameter value u_i (Greene, 2008). To achieve properties of cross-sectional data a well-known estimator proposed by Kuosmanen *et al.*, (2014) is now comparatively better (Cornwell and Schmidt, 2008). Even if the variables incorporated with the analysis are uncorrelated, ignoring the dependence of the inefficiency on

indicator variables it may be caused the first step of estimation of technical efficiency. As such, the second step is likely to be bias downward. Assuming input, indicator variables are independent it will be easier to grasp the underlying results by constructing the JLMS estimates. The JLMS efficiency scores act as an estimator shrinking towards the mean. Different assumptions about the production frontier affects the efficiency estimates with their statistics of the selected area may help to decide the efficiency of models enlisted in the following the Table 6.17.

Table 6.17: JLMS estimators of having no loan category

Statistics	Natore	Bogura	Rangpur	Dinajpur
Mean	0.918	1.000	0.956	0.984
SE	0.059	0.000	0.019	0.009
IQR	0.082	0.000	0.018	0.009
Min	0.752	1.000	0.875	0.963
25%	0.882	1.000	0.949	0.981
50%	0.939	1.000	0.959	0.986
75%	0.963	1.000	0.967	0.990
Max	0.989	1.000	0.986	0.995
<i>n</i>	53	14	66	22

(Source: Author's surveyed data)

Natore district shows the minimum mean efficiency among the districts while Bogura shows the efficient unity. The minimum JLMS records show the gradual increasing trend from Natore to Dinajpur except for Bogura due to the fully efficient model. The increasing patterns of the efficiencies are marked from the percentiles.

The technical efficiency of Loan category of farmers has estimated the relevant summary statistics for the estimated technical efficiencies are given in Table 6.18.

Table 6.18: JLMS estimators of having loan category

Statistics	Natore	Bogura	Rangpur	Dinajpur
Mean	0.999	0.970	0.970	0.963
SE	0.000	0.002	0.001	0.025
IQR	0.000	0.038	0.024	0.016
Min	0.999	0.882	0.914	0.812
25%	0.999	0.955	0.964	0.961
50%	0.999	0.981	0.978	0.970
75%	0.999	0.993	0.988	0.976
Max	0.999	0.999	0.999	0.989
<i>n</i>	35	84	18	58

(Source: Author's surveyed data)

Both minimum and maximum efficiency occurs for Dinajpur district among the districts while Bogura shows the efficient unity. The higher percentiles are noted for Natore district among the selected districts.

6.6. Diagnostics of fitted models

A density plot represents the distribution with its data points. At a glance, its peaks locate the highest concentration of points and the modal values, the skewness and the kurtosis of distribution may understand from the graph quickly. As such, the density plot of four selected districts, Natore, Bogura, Rangpur and Dinajpur are computed and are shown in Figure 6.1.

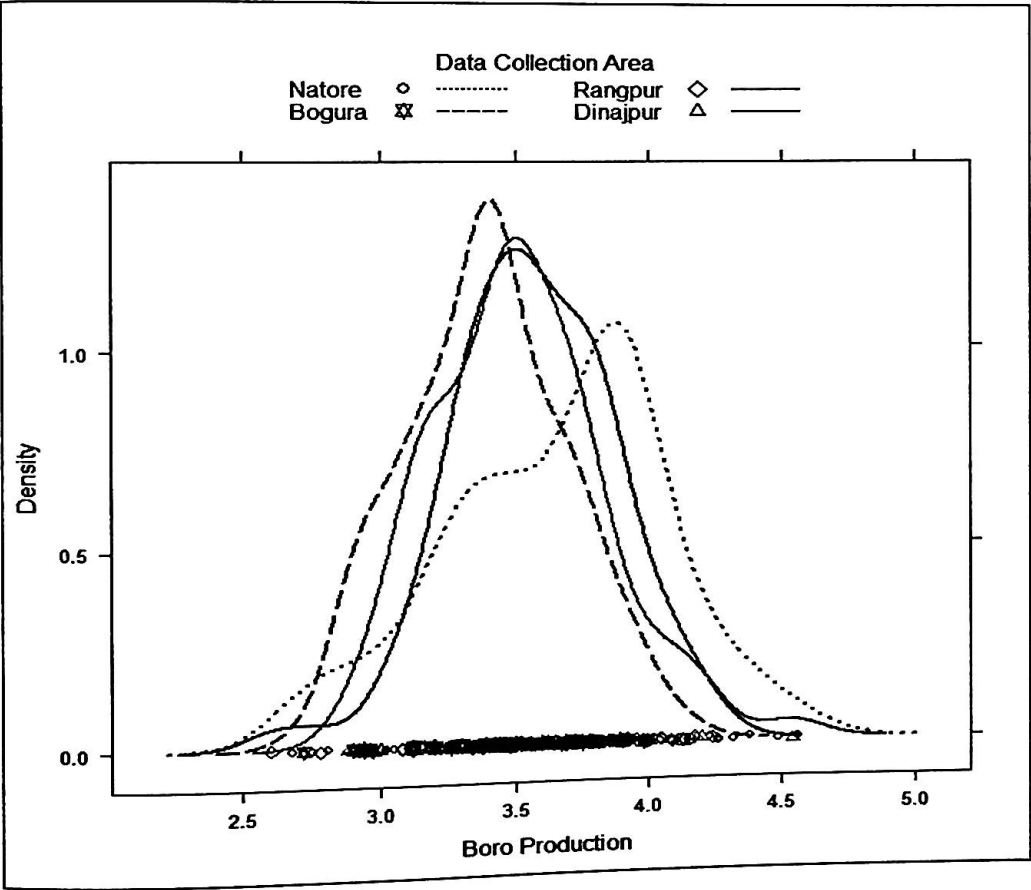


Figure 6.1: Density plot of Boro production of study area

(Source: Author's surveyed data)

From the Figure 6.1 it shows that except Natore all three districts are showing similar pattern relatively. However, Natore districts are somehow different and it is near to bimodal pattern of the Boro production.

The production frontiers under Half-Normal assumption of errors against fitted production are given in Figure 6.2 showing different pattern for Bogura district while others three districts, Natore, Rangpur and Dinajpur are somehow similar. The leptokurtic kurtosis for Rangpur and Dinajpur are notable from the Figure 6.2.

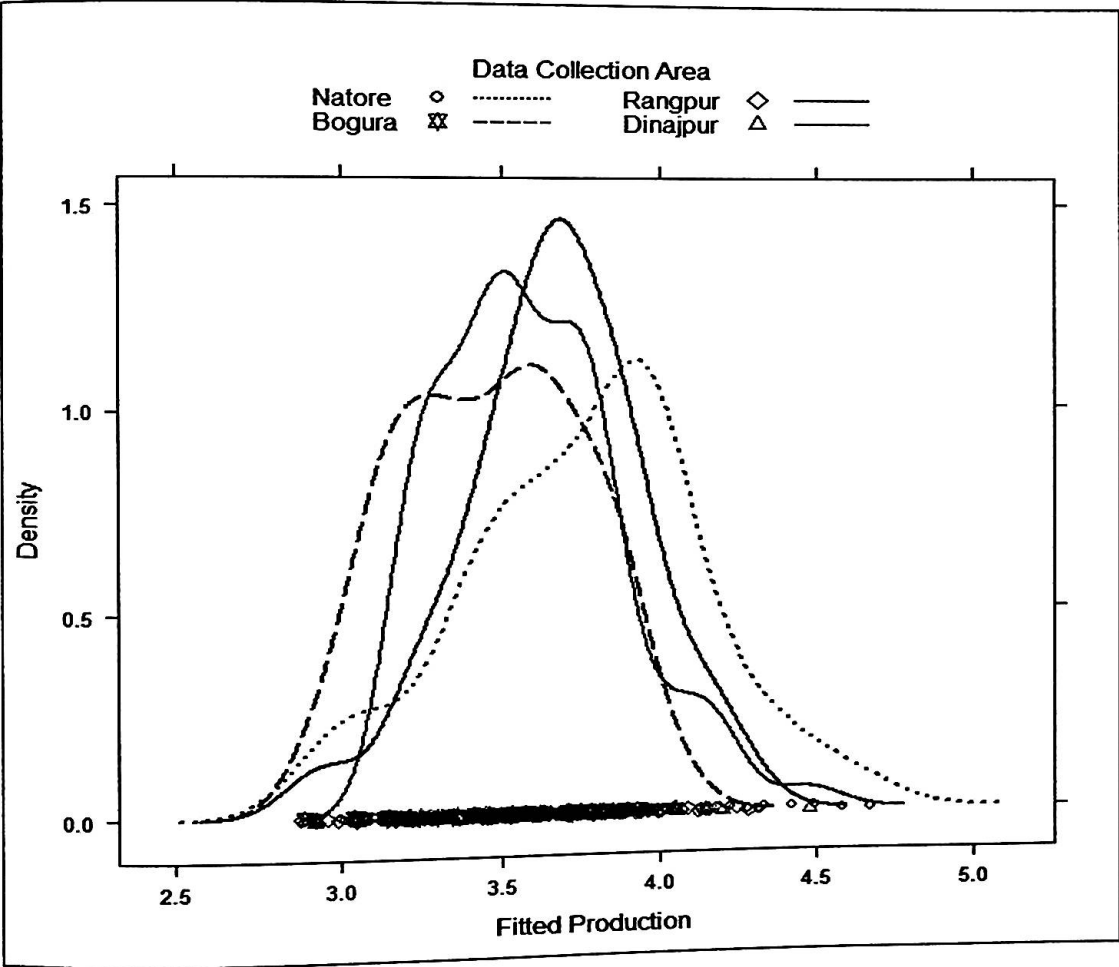


Figure 6.2: Density plot of fitted production of study area

(Source: Author's surveyed data)

The density plot of technical efficiencies scores of MLE estimates of the logarithmic modified stochastic production frontiers of four districts are given in the Figure 6.3.

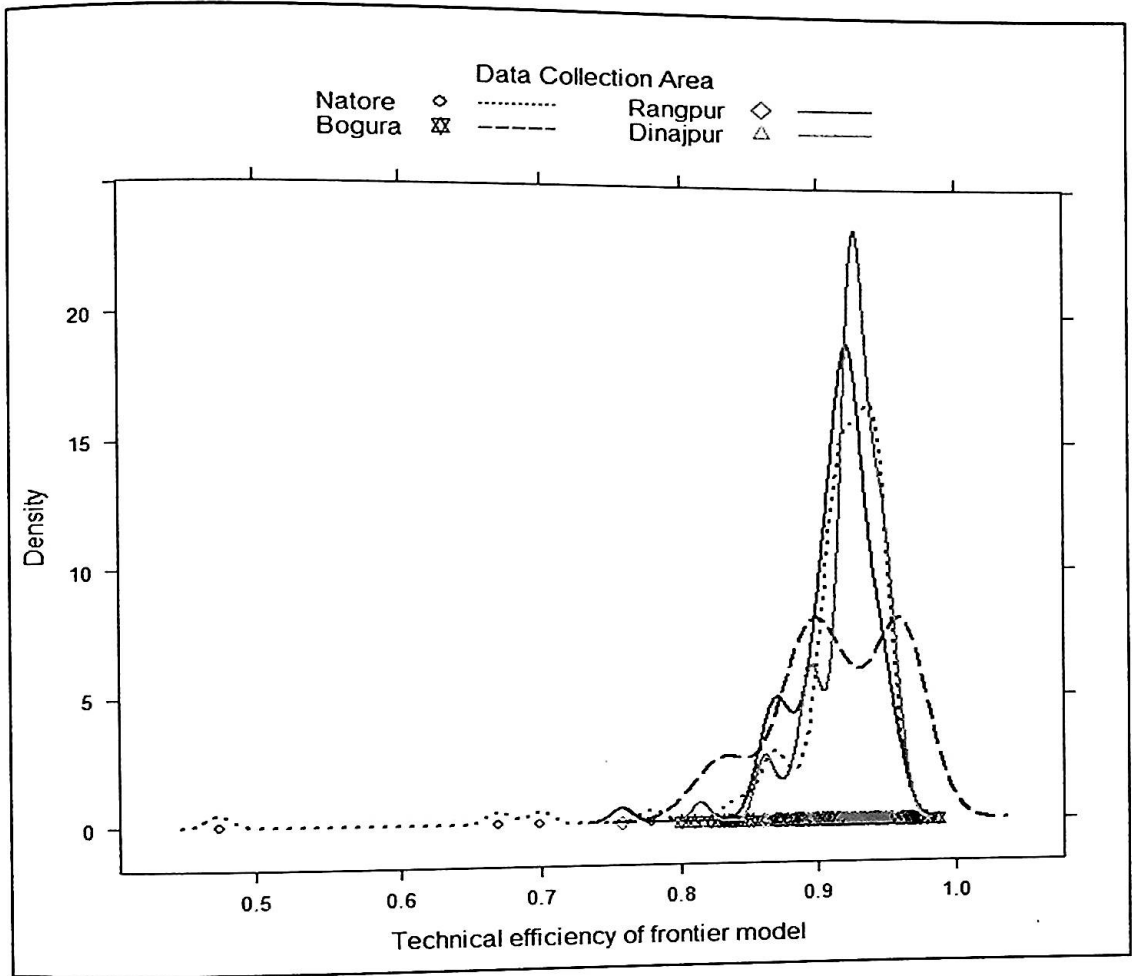


Figure 6.3: Density plot of technical efficiency of models

(Source: Author's surveyed data)

The efficiency scores of all four districts from Figure 6.3 are skewed towards the right and most of the densities are concentrated to the neighbour of 0.95 for Rangpur and Dinajpur. But a higher proportion of frequencies are concentrated to two points indicating that the distribution for Bogura district shows a distinctive bimodal pattern with wide variability of the scores indicating that some of the farmers are very efficient than others.

The estimated residuals of the model for the pooled data ($n=350$) are plotted against fitted logarithmic production of Boro rice are shown in the Figure 6.4. In addition, such residuals are fitted against fitted production by Loan category are given in Figure 6.5.

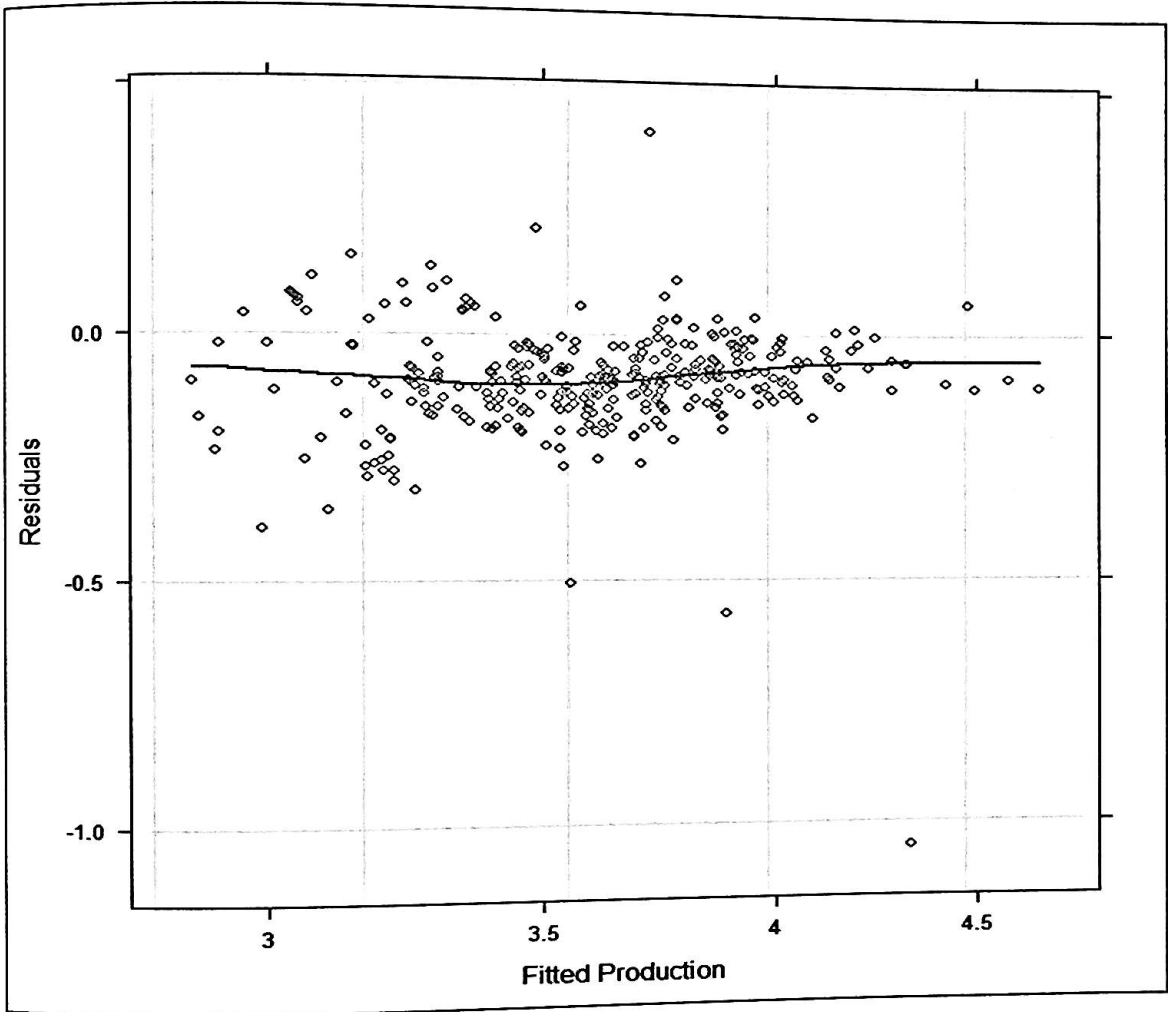


Figure 6.4: Estimated residuals against fitted production

(Source: Author's surveyed data)

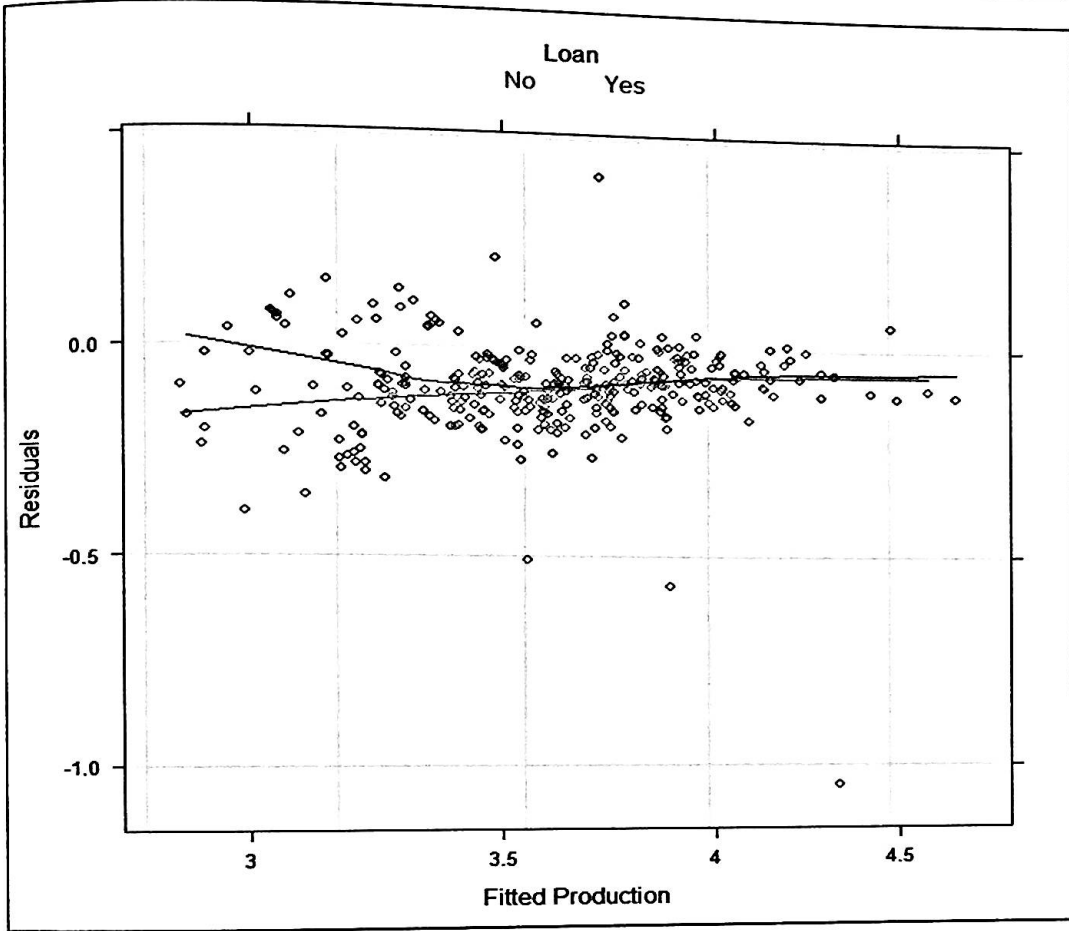


Figure 6.5: Estimated residuals against fitted production by loan

(Source: Author's surveyed data)

It is evident from Figure 6.4 that although somehow the fit is good a slight deviation of from exactness of model is seen due to irregular behaviour of a few estimated residuals are noticed. As Loan may be a supportive variable in producing Boro rice for the firm level farmers of the selected districts, we have been given concentration on the credit (Loan) receiving category of farmers that are shown in Figure 6.5. Despite of some distanced residuals the mean line of non-receiving Loan category is more concentrated than receiving Loan category.

To judge the fitted pattern of technical efficiencies either it follows the basic assumptions or not the figures Figure 6.6 are drawn for the credit (Loan) receiving category of farmers.

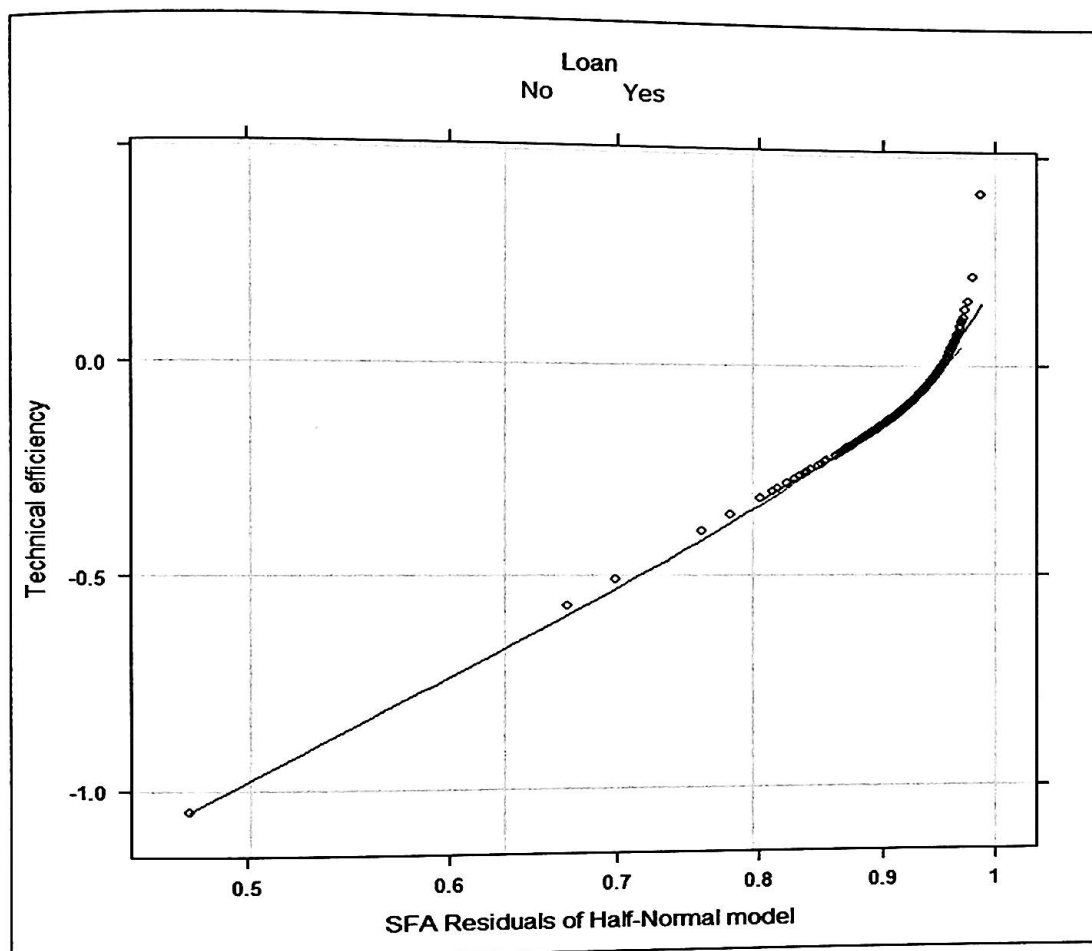


Figure 6.6: Plot of efficiency for Half-Normal SFA model by loan

(Source: Author's surveyed data)

The farmers of non-receiving Loan category are linearly concentrated but receiving Loan category is not linearly concentrated with a straight line. Plot of technical efficiency against the inefficiency residuals by loan category of Half-Normal assumption of error are given in the Figure 6.7.

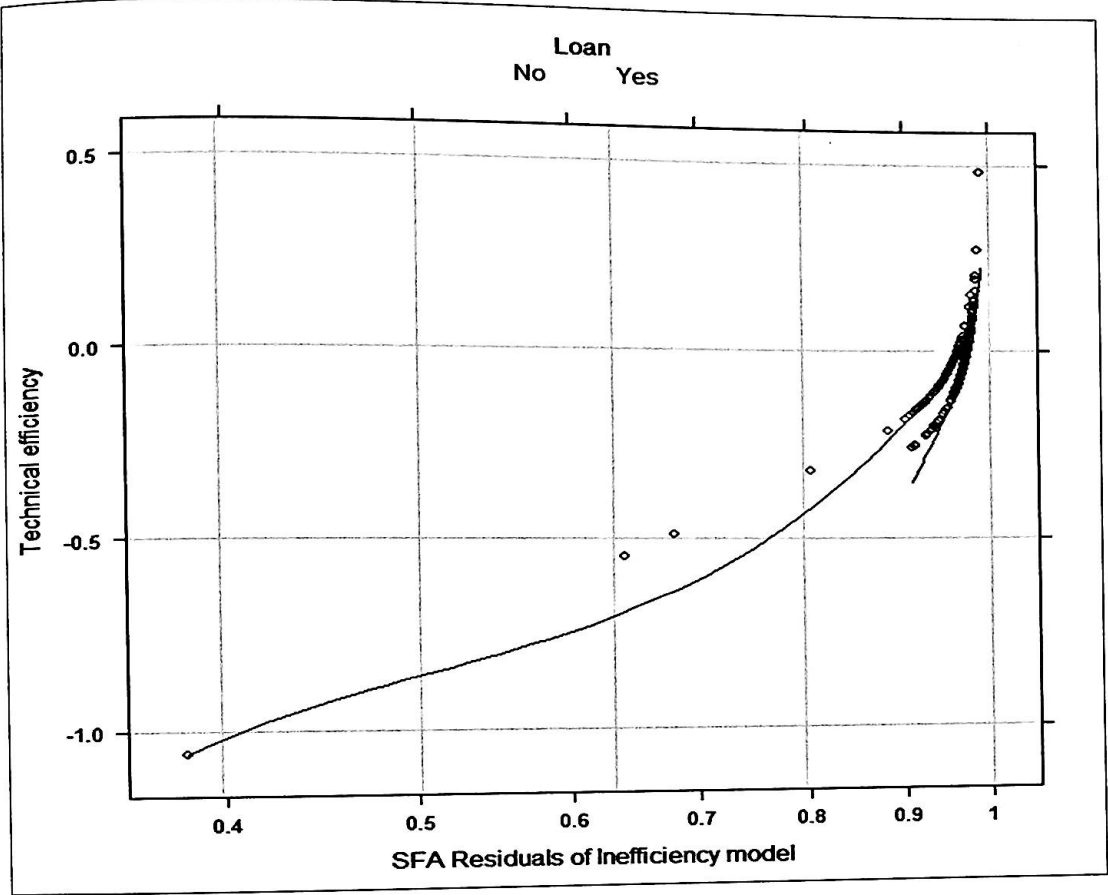


Figure 6.7: Plot of efficiency against Half-Normal inefficiency residuals by loan

(Source: Author's surveyed data)

The errors of inefficiency model under Half-Normal assumption for loan category indicating that the farmers who received loan are more concentrated to the pink color in the fitted line but farmers of non-loan-receiving category are somewhat deviated from the fitted line. Therefore the loan receiving category are seems to be organized and more concentrated with their firm management as well as to the Boro production.

CHAPTER VII

CONCLUSION AND POLICY IMPLICATION

CONCLUSION AND POLICY IMPLICATION

7.1. Introduction

Investigation of determinants of production risk and efficiency and/or inefficiency may have important role based on stochastic production framework as well as Stochastic Frontier Analysis to the improvement of such sector are taken into consideration in this study. The conclusions of the study incorporated accordingly in this chapter followed by the suggestions for policy implications for the improvement of the existing level of inefficiency of farmers of the Northern region as well as the country.

7.2. Conclusion

Agriculture continues to dominate the economic scene of Bangladesh, accounting maximum share of GDP and it provides employment to more than 40.62% of the total labour force. According to the objectives an attempt have been made to estimate the technical efficiency as a measure of how well inputs are being used towards production of Boro rice of Northern region of Bangladesh with the help of four selected districts of 350 firm level producers. As we are dealing with the firm-level primary data of Boro producers, it is essential to investigate the integrated management of the farmers in both the efficiency and inefficiency ground. The MLE estimators of the models have computed under the Half-Normal assumption of errors. The appropriateness of recommending SFA models have been judged individually for the selected districts.

The important variables Fertilizer and Land are found to be positively significant impact on the output variable for Rangpur district and good fit of the model with the correctness of the specified Half-Normal assumptions. The estimated variance ratio parameter, gamma is highly significant indicating that about 77% of the difference between the observed and output frontier was primarily due to the factors under the control of the farmers. further the average technical efficiency are estimated as 94% implying that on an average the sampled farmers tend to realize around 94% of their technical abilities. Therefore, it is possible to improve the yield by 6% by following efficient crop management practices without increasing the level of inputs application.

Labor, Fertilizer, Land and Pesticide are significant at 1% level may be considered as the determinants of Boro rice output in Dinajpur district. Among the significant variables Labor, fertilizer and land have found to be positively related to the output of Boro rice but pesticide have a negative significant impact on the output. It may be due to improper or over utilization of pesticide. Besides, positive coefficient value of harvesting and negative coefficient value of seed are not significant, implying that these variables have no effect on Boro rice output of Dinajpur. The goodness of fit, and the correctness of the distributional form assumed for the composite error term and the variance ratio parameter gamma (γ) which found to be significant at 1% level expressing that about 92% of Boro rice output deviations are caused by differences in farm level technical efficiency as opposed to the random variability that are outside their control of the producers. The mean technical efficiency is 0.96 which indicates that the selected farms remained near the frontier and there is less scope to further increase the productivity at the existing technology. The results for the farmers of Natore district revealed that Harv and Fert are insignificant and the coefficients of labor, pesticide, seed and land are positive which confirm that, there is a positive relationship between these inputs and the output of Boro rice. Pesticide had the

biggest positive elasticity (0.427), which was strongly significant at 1% level. This implies that 1% increase in pesticide quantity significantly increased Boro rice output by 0.42%. This indicated that the Natore district is one of the most diseases and pest affected areas in Boro farming. The estimated sigma square is significantly different from zero and there are about 90% of variations of Boro rice output from the frontier were attributed to technical inefficiencies of the producers confirms by estimated gamma.

The variables Harv, Pest, Fert are significant indicates potential of increasing the level of production through raising their usage. The Seed and Labor are found as insignificant. However, the effect of Pesticide was found significant negative which indicates it's over or improper use in production of Boro rice. The goodness of fit and correctness of specified distributional assumption of the composite error term have identified and gamma (γ) is insignificant with the mean technical efficiency are approximately equals to unity. As such, the inefficiency parameters are supposed to have no such effects on the output of the farmers.

The estimated coefficients of the model of pooled data were found to be positive and they were all statistically significant. The estimated coefficient of labor, harvesting, pesticide, seed, fertilizer, and land were found as 0.013, 0.034, 0.037, 0.235, 0.543, and 0.007 respectively indicating that all these variables have positive contribution to the Boro production. The likelihood chi-square for variance parameter is significant and it supports to reject the null hypothesis that the inefficiency is a significant portion of the total error, and SFA is appropriate for the analysis. The technical abilities of farmers confirms by the measured mean TE 0.914 and it also confirms remaining 9 percent output loss may be due to the inefficiency in the Boro farming system or due to the inefficiencies among the sample farmers or both.

The estimated γ is 0.710 indicates the presence of a significant effect of inefficient variables in the model and is justified to use the inefficiency model for Boro production. Therefore, there are about 71 percent of differences between the observed and the maximum production frontier outputs could be due to input variables of resources and the rest 29 percent could be due to random factors outside the control variables. The inefficiency model may cause the individual farmers in their decision purpose and it is evident from the result that variables Labor, Harv, Pest, Seed, Fert, and Land affect the farm level activities of the study area.

Assuming independent of the input indicator variables it will be easier to grasp the underlying results by constructing the JLMS estimates. As the JLMS efficiency scores act as an estimator shrinking towards the mean and may achieve properties of cross-sectional data, following traditional literatures the JLMS efficiency scores production frontier are considered in this research. The results of Loan non-receiving classes are enlisted in the Table 6.17. It is evident that Natore district shows the minimum mean efficiency among the districts while Bogura shows the efficient unity. The minimum JLMS records show the gradual increasing trend from Natore to Dinajpur except for Bogura due to the fully efficient model. The increasing patterns of the efficiencies are marked from the percentiles.

The technical efficiency of Loan receiving class of farmers has estimated the relevant summary statistics for the estimated technical efficiencies are given in the Table 6.18. It is clear that both the minimum and the maximum efficiency occur for Dinajpur district among the districts while Bogura shows the efficient unity. The higher percentiles are noted for Natore district among the selected districts also.

According to Battese and Coelli (1995), the combined estimation of the model comprises both the efficient frontier of agricultural production and the influential variables for the inefficiency of production in the agricultural area of interest of firm level agricultural, the data sets of the selected districts have been analysed. The goodness of fit and correctness of assumptions about the specified distribution of the composite error terms for Natore and Bogura have found while the proportion of deviation from frontier that is due to inefficiency estimate was zero are not significant. Therefore, instead of inefficiency model SFA output may be considered here. Nevertheless, opposite scenario are noticed from the result divulged for the districts Rangpur and Dinajpur. Finally, there is minimal scores 4% of increasing the efficiency, by adopting the technology and techniques used by the best Boro rice farmer for Rangpur while for Dinajpur 3% efficiency can be increased.

Agricultural Loan may play vital role for the development of small farmers and which may influence farmers' ability to adopt agricultural supports systems to enhance the productivity.

How significantly reduces production (in)efficiency by this parameter have been investigated with the help of the researcher-surveyed data sets of the study areas. Gamma is significant for Loan receiving group for Rangpur and Dinajpur districts while it is insignificant for Non-Loan receiving groups. The districts Bogura and Natore, reverse results for gamma is found. However, the mean efficiency of Loan receiving group decreases in compare to the Non-receiving group for Rangpur and Dinajpur while opposite figure is found for the districts of Bogura and Natore.

Further, the inefficiency effects of the models have tested for different null hypotheses. The differences between Loan and Non-Loan group Natore and Bogura districts have found while for the districts Rangpur and Dinajpur no such equal contribution of variables for both Loan and Non-Loan group have discovered.

The graphical presentation of densities against actual production of the districts locate the highest concentration of points and the modal values, the skewness and the kurtosis of distribution may understand from the graph quickly. Except Natore all three districts have been found to behave similar pattern. However, Natore districts are somehow is near to bimodal pattern of the Boro production.

The production frontiers under Half-Normal assumption of errors against fitted production shows different pattern for Bogura district while others three districts, Natore, Rangpur and Dinajpur are somehow similar. The efficiency scores of districts are positively skewed indicating that a higher proportion of them are among the high efficiency groups. Nevertheless, a distinctive bimodal pattern with wide variability of the scores have found for Bogura indicating that some of the farmers are very efficient than others. Although somehow the fit is good, a slight deviation of from exactness of model is seen due to irregular behaviour of a few estimated residuals. The concentration has been given on the Loan receiving category of farmers. Despite of some distanced residuals the mean line of non-receiving Loan category is more concentrated than receiving Loan category. The farmer of non-receiving Loan category is linearly concentrated but receiving Loan category is not linearly concentrated with a straight line.

As its growth has important linkages with economic related performance as well as different economic activities in Bangladesh, the authorities are need to concentrated to the Boro production as well as to improve the farmers existing facilities. Although in the last decade, the Government has taken good initiatives the current study suggested to nourish the inputs and extends the technological supports for the betterment of the country.

7.3. Suggestions for policy implications

Currently, agriculture sector contributes one-fifth share of the total GDP of Bangladesh and Boro production is contributory among all other rice varieties. As such the study of identifying the determinants of Boro rice producers' technical efficiency (TE) of Northern region in Bangladesh have performed. Based on the findings issues raised in this research attached herewith for the policy decision purposes.

- Need to improve the agricultural support systems and proper training facilities for the Boro producers with an extension of existing technological supports systems
- Proper coordination and sufficient credit facilities are suggested for the marginal Boro producers
- It is required to handle properly the environmental hazards issues related to the production with necessary care of the traditional major inputs such as fertilizer and pesticide, quality seeds etc.
- It need to ensure the modern equipment facilities like, labour saving harvesters or related equipment's

Even though the BMDA provides irrigation for Boro rice farmers, all the producers are not getting advantages in this regards, expansion of the irrigated area/scheme are advised to facilitate adequate supply of water for Boro producers.

- Although from the last decade, Bangladesh Government is taking care about the required facilities of marginal farmers, it needs to assist farmers by good storage facilities, market management systems so that the farmers can get the optimum price.

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APPENDIX

APPENDIX I

Questionnaire number: _____ Date: _____



Department of Statistics
University of Rajshahi, Bangladesh

Interview Schedule for the PhD research entitled, “FACTORS AFFECTING THE TECHNICAL EFFICIENCY OF BORO RICE PRODUCERS OF NORTHERN REGION OF BANGLADESH”

(The information should be used in research purposes with confidentiality)

Section: 1 (Identification of Farmers)

1. Name of Respondent: _____

Union: _____ Ward: _____ Village _____

Thana _____ District: _____ Mobile No. _____

Section: 2 (Socioeconomic and Demographic Information)

2. Age: _____ years

3. Sex: Male ☐ Female ☐

4. Marital Status: Single ☐ Married ☐ Widowed ☐ Other ☐

5. Family size (living and eating together): _____

(No. of dependents _____ Adults: _____ Children: _____)

Age group	Sex	
	Male	Female
0 - 7		
8 -18		
19 - 64		
64 +		
Total		

6. Level of Education (in schooling years) _____

7. Religion: Christianity ☐ Hindu ☐ Islam ☐ Others ☐

8. Ethnicity: Yes ☐ No ☐

9. Main occupation: Farming ☐ Teaching ☐ Trading ☐ Service ☐ Others ☐

10. Do you have a second occupation: Yes ☐ No ☐ (If yes, Name _____)

11. How long have you been a farmer (farming experience)?
_____ years

12. Do you belong to a co-operative/farmer based society?

Yes ☐ No ☐ (Year _____)

13. If yes to 12 above, do you receive any assistance from the organization?

Yes ☐ No ☐

(Training ☐ Machinery services ☐ Equipments ☐ Credit

☐ Storage ☐ Marketing Services ☐)

14. Do you have access to agricultural loan?

Yes ☐ No ☐ if yes, what is the source?

(Bank ☐ GOs ☐ NGOs ☐ Cooperatives ☐ Friends or relatives ☐ Money lender ☐)

15. How much credit did you use in last season? BDT _____

Section: 3 (Information of Inputs and Output of Boro Rice)

16. What was your total farm land size?

No. of plots	Area Bigha/decimal	Farm type	Production (kg)
		1. Inherited	
		2. Owned	
		3. Rented	
		4. Borrowed	
Total			

17. What was the major source of labor? Family/ Hired/ Others

18. Number of labour in last season _____

19. How many man-days do you work on the farm per week? _____

20. Did you hire people to work on rice production during the last season?

Yes ☐ No ☐

Farm Operation	No. of people	No. of man days	Wage Rate/day	Total Cost
Land preparation				
Planting				
Weeding				
Fertilizer use				
Pesticide use				
Irrigation				
Harvesting				
Total				

21. Did you get seed timely?

Yes ☐ No ☐

22. What kind of seeds did you planted: Improved varieties/Local varieties/ others

23. Sources of seed?

(a) Own (b) Neighbor's (c) Local market (d) GO Seed dealer/BADC

24. Quantity of used seed: _____ kg.

25. Cost of seed: _____ Tk.

26. Information on used chemical fertilizers

Name of the fertilizer	Quantity of fertilizer used (kg)	Price/kg	Total Cost
Urea			
TSP			
DAP			
MOP			
Gypsum			
Others			
Total			

27. Have you used manure on the Boro rice during this crop season?Yes ☐ No ☐**28. Information on used pesticide**

Name of the Pesticide	Quantity of Pesticide used (unit)	Price/unit	Total Cost
Total			

29. Which technique used for harvesting?

(a) Reaper (b) Combine harvester (c) Manually

30. Harvesting cost.....

Section: 4 (Information of Farming Activities on the Boro Rice Output)

31. What type of farming system you practice: Mono/Mixed farming/Others ?
32. Have you received any form of training on use of input in Boro rice production?
- Yes ☐ No ☐
33. If yes, who provided the training: GO/NGO/Farmer/others _____
34. Do you usually get extension services?
- Yes ☐ No ☐
35. If yes, then source: GO/NGO/Both/others
36. The visit by agricultural extension agent: none /regularly/occasionally
(Monthly average times _____)
- a) Drought b) flood c) Hurricane d) Temperature e) hail storm e) other
37. Does your cultivable land have access to irrigation facilities?
- Yes ☐ No ☐
38. If yes, what is the name of your service provider?
- (Deep tube well by BMD/ Own motor or shallow tube well/ others)
39. If yes, then from which source: Groundwater/surface water

Thank You Very Much for Your Time and Patience

**PUBLICATIONS FROM THIS
DISSERTATION**

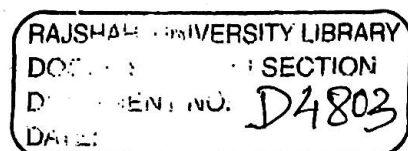
APPENDIX II

Journal papers

1. Kundu, R. K., and P. K. Karmokar (2021). Technical Efficiency of Boro Producers and Its Distribution: An Evidence from Natore District, Bangladesh. *Global Scientific Journal*. Vol. 9(3), pp. 2241-2249.
2. Kundu, R. K., M. R. Pervej, M. M. Khatun and P. K. Karmokar (2020). A Stochastic Frontier Modeling of Boro Rice Farmers in Bogura Districts of Bangladesh. *International Journal of Advances in Agricultural Science and Technology*, Vol. 7(5), pp. 20-27.

Conference paper

1. Kundu, R. K., M. R. Pervej and P. K. Karmokar (2019). A Comparison of Technical Efficiencies of Boro Rice Producers between Natore and Bogura Districts of Bangladesh. Proceedings of the 7th International Conference on Data Science and SDGs: Challenges, Opportunities and Realities, December 18-19, 2019. University of Rajshahi, Bangladesh.



29. 3. 2023