2007

Supply Response of Major Agricultural Products in Bangladesh: A Cointegration and Error Correction Modelling Approach

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SUPPLY RESPONSE OF MAJOR AGRICULTURAL PRODUCTS IN BANGLADESH: A COINTEGRATION AND ERROR CORRECTION MODELLING APPROACH

By

Gazi Hasan Kamal

A Dissertation
Submitted to Rajshahi University for the Degree of

Doctor of Philosophy

in

Economics

Institute of Bangladesh Studies
Rajshahi University
Bangladesh

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June 2007

Declaration

I do hereby declare with due solemnity that the dissertation entitled **Supply Response of Major Agricultural Products in Bangladesh: A Cointegration and Error Correction Modelling Approach** submitted to the University of Rajshahi, Bangladesh, for the degree of Doctor of Philosophy is an original work. No part of this dissertation, in any form has been submitted to any other university or institution for any other degree or diploma.

28.06.07

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Certificate

With reference to this dissertation entitled **Supply Response of Major Agricultural Products in Bangladesh: A Cointegration and Error Correction Modelling Approach** submitted by **Gazi Hasan Kamal** to the University of Rajshahi, for the Degree of Doctor of Philosophy, I certify that this research done under my direct supervision and guidance is an original unpublished work.

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Acknowledgements

First of all, I would like to express my gratitude and deep sense of reverence to my supervisor, Dr. Abdul Wadud, for his supervision and guidance. I learned a lot from him. He made a lot of efforts in checking my writing. I am highly impressed by his friendly approach in dealing with me although I claim to be his student.

I appreciate valuable suggestions and prudent counselling from the Director of Institute of Bangladesh Studies (IBS), Dr. Abul Basher Miah, and other faculty members.

My thanks also go to the Department of Economics in particular Dr. Tarique Saiful Islam and Dr. Elias Hossain for their comments and suggestion. I thankfully remember Atoar Rahman and Afzalur Rahman for their co-operation and support. Thanks to Ph.D. researcher Abdul Malek, my Eviews programming skills were greatly enhanced by him. I am thankful to my friend Ph.D fellow Saleheen, who provided me many opportunities.

I would like to acknowledge for offering all kinds of academic support and facilities for this research work to Institute of Bangladesh Studies, Bangladesh Agricultural Research Council (BARC), and Bangladesh Agriculture University. I am further thankful to Bangladesh University Grants Commission (UGC), Social Research Council (SSRC) for fellowship and research grants respectively.

At last, I would like to recall my parents who are my constant inspiration. The encouragement and mental support by my wife Moona was a great strength for me. During my doctoral program, I could not properly take care of my baby Shadman and Modhurima; they missed me a lot.

Abstract

The aim of this study is to increase our understanding of the specification and estimation of agriculture supply response in Bangladesh as well as to provide instrument for agriculture planting decision and price policy by using econometric tools–cointegration and error correction model with careful attention to time series data to avoid spurious regression of traditional econometric analysis. It is observed that farmers adjust their production rotted on the basis of price phenomena in the market. Price mechanism and its impact on farmers' supply behaviour are crucial issue for policy makers. In this connection price incentives or price support mechanism accelerate output supply in a country like Bangladesh. For this reason farmers' reaction or response to financial incentives is a prime concern for policy makers and for the government.

Econometric model has been specified on the basis of theoretical arguments. This study also provides a theoretical framework that leads to formulate an empirical model from various aspects with price and non-price variables.

The study is designed to identify statistically the acreage responses of major agricultural products (rice and wheat) in Bangladesh. Time series data have been used in the analysis for the period 1972-73 to 2003-04. Econometric and statistical techniques are applied to estimate the supply responses of rice and wheat at the national level. Long-run own price acreage elasticities for aus and boro are 0.98 and 0.95 (near to unitary elastic) respectively. The results show that own price acreage elasticities for aman and wheat are 0.31 and 0.25 (inelastic range) respectively in the long-run.

List of Abbreviations

ADF	:	Agumented Dickey-Fuller
AIC	:	Akike Information Criterion
APP	:	Average Physical Product
ARMA	:	Autoregressive Moving Average
BADC	:	Bangladesh agriculture Development Corporation
BARC	:	Bangladesh Agriculture Research Council
BBS	:	Bangladesh Bureau of Statistics
BIDS	:	Bangladesh Development Studies.
DAM	:	Directorate of Agriculture Marketing
DAP	:	Draught Animal power
DF	:	Dickey–Fuller
DGP	:	Data Generating Process
ECM	:	Error Correction Mechanism
ECT	:	Equilibrium Error Term
FAO	:	Food and Agriculture Organization
FCD	:	Flood Control Drainage
FCDI	:	Flood Control Drainage and Irrigation
GDP	:	Gross Domestic Product
GOB	:	Government of Bangladesh
HYV	:	High Yielding Variety
LDCs	:	Least Development Countries.
LR	:	Likelihood Ratio
MAE	:	Mean Square Error

ML	:	Maximum Likelihood
MV	:	Modern Varieties
NLS	:	Non-Linear Least Square
OLS	:	Ordinary Least Square
SAP	:	Structural Adjustment Program
SBC	:	Schwartz Information Criterion
TPP	:	Total Physical Product
VAR	:	Vector Auto Regressive

Contents

Chapter 1
Introduction

1.1 Introduction

Profits or loss in farming depend more on prices than anything else. It is observed that farmers adjust their production rotted on the basis of price phenomena in market. In a dynamic world, past and present conditions help shape future conditions. So estimating present and future price is an important function in the production economics. In Least Development Countries (LDCs) price policies have great impact on farmer's crop production and resource allocation. More specifically, price and non-price variables influenced farmers' supply decisions. This study will consider both price and non-price variables as an agricultural supply response factors through econometric representations. One of the most important issues in production economics is supply response since the responsiveness of farmers to economic incentives largely determines agriculture's contribution to the economy. Agricultural pricing policy plays a key role in increasing both farm production and incomes, and fundamental to an understanding of this price mechanism is supply response (Nerlove and Bachman, 1960).

In Bangladesh GDP growth is highly correlated with agricultural growth and it also significantly contributes to overall economy through increased income to the large rural population. Furthermore, agricultural growth promotes diversification and development of non-farm activities in the rural economy. It also supports industrial growth. The production performance of the agriculture sector in Bangladesh, particularly crop sub-sector, has considerable bearing upon the rate and structure of poverty and malnutrition, the trade balance and the government fiscal position, and consecutively upon the rate of growth of the Bangladesh economy as a whole (Hossain, 1991:24)

On the basis of contribution to GDP, the crop sub-sector dominates the agriculture sector contributing 12.19 percent to total GDP (Bangladesh Economic Review, 2006). Practically all the increases in agriculture production have been associated with crop production. Rice is the principal crop of the country and wheat has been established as the second most important cereal crop in Bangladesh. Food grains are the main consumption item, accounting for 35 percent of total consumption expenditure and more than 80 percent of total calorie intake (Dorosh, Shahabuddin and Rahman, 2002: 47). It is clear that supply-demand balance of food grain is the dynamics of Bangladesh agriculture sector. Bangladesh has got the most fertile lands but due to paucity of capital and lack of knowledge of new inputs and techniques, its yield per acre is one of the lowest in the world (Statistical year Book 2000, 21st edition). Nevertheless, Bangladesh is marginally deficit in food grains. So, there is a huge potentiality in crop sub-sector for the following perspectives:

i) Mitigating the food deficit and giving high standard of living by increasing food grains production.

ii) High production of food grains may become regular exportable items

The above aspects of crop sector productivity need effective government strategy, actions and policy directions. Price policy in this context is a major lever for influencing increase in crop production investment in agriculture, resource allocation and the level of agricultural income and its distribution. Finally, it leads to the supply of agricultural production. This study is to analyse the supply response in Bangladesh economy and determine how producers will respond to the changes in product price and factors prices, in technology and in access to certain constraining factors of production.

Aus, Aman and Boro are the three main types of rice, being harvested in Bangladesh. Due to the existence of intense monsoon in Bangladesh, aman (wheat season crop) and boro (dry season crop) are being produced heavily in the low-lying lands.

The total production of rice in 2005-06 is 280.76 lakh metric tonnes in which the share of aus, aman and boro are contributed 6.2, 38.46 and 55.28 percent respectively. Out of the last twelve years the highest growth rate of production is experienced in 1999-00 (Appendix 1.1). The growth rate of total rice production is 3.6 percent over the last ten years (1995-2005).

In case of disaggregated rice production for aus, aman and boro, there was decreasing trend of aus production (Appendix 1.2). For aman and boro there are increasing trend, particularly in 1999-00. Aman experienced a robust growth and in 1998-99. Boro production growth was impressive. The area cultivated for aus shows a decreasing trend whereas for boro it is increasing. Aman was almost at stagnancy.

In case of wheat production for the last five years it is observed that there is a decreasing trend of wheat production. In 2005-06 wheat production is only 7.35 lakh metric tonnes and in 1998-99 it was 19.08 lakh metric tonnes. Wheat production in 2005-06 is nearly 60 percent less compared to production in 1998-99. From 1990-91 the wheat production showed upward trend and it was peak in 1998-99. Just after the year 1998-99 wheat production showed decreasing trend. But its yield rate is impressive over the last ten years. Over the last twelve years, the total area of cultivated land for rice and wheat has shown increasing trend. The yield rate is also showing an upward trend though it is below one.

Supply response is the most important issues in production economics as well as any agro-based country like Bangladesh. Supply of agricultural response is mainly related with two factors, one is individual product price elasticity and another is aggregate elasticity to the factors supply. The supply response, according to 'Nerlove and Bachman' (1960) is to improve understanding of the price mechanism of supply response. It is observed that the supply response of crops to changes in real price levels in developing countries is weak. In Bangladesh, there is however a paucity of empirical works relating to this critical area. Estimates of supply response applying modern econometric tools, like cointegration; error correction technique would yield valuable insights into the potential for using price policies in agriculture. In Least Developed Countries (LDCs) where the majority of people live in rural areas and consumers spend up to 80 percent of their income on food, agricultural price is more important. Given their importance, price policies have been the cornerstone of farm programs in many countries.

Price policy is a major lever for influencing the growth of the agriculture sector. The generation of investible surplus and its allocation, and the level of agricultural income and its distribution can be influenced by agricultural price policy. It is therefore, vitally important to understand the scope and limits of price policies in Bangladesh agriculture.

Overall resource allocation is the main concern issue, which is associated with the proposed term in the case of agricultural sector. Moreover, it has significant linkages with the rest of the economy. The prime concern for development efforts in Bangladesh rests with agricultural development. In the agriculture sector, the crop sub-sector dominates practically all the increases in agricultural production which associates with crop production.

Rice, the principal crop of the country, supplies main food to the people and feed to the domestic animals. It is also the commodity of trader in internal marketing. The domestic production of rice is still not sufficient to meet the demand for food, which is growing at a rate of 2 percent per annum (Jabbar and Alam, 2002: 16). Wheat has been established as the second most important cereal crop in Bangladesh. The domestic demand trend for wheat is upward. The national average yield of wheat is only 1.9 t/ha as against 3.0 to 6.5 t /ha noted at different research stations (Rahman and Karim, 1999: 191). The yield gap between potential and national average is associated with many production factors. *So, the food problem in the country is viewed as supply oriented.*

High instability of agricultural prices is a problem to the Bangladesh farmers. Inter-year and intra-year price fluctuations are excessive for important crops like rice, Jute and wheat.

Unforeseen natural calamities have lowered production and investment in agriculture. Climatic unpredictability, particularly excess or inadequate rainfall in different production periods makes agricultural production a risky business enterprise.

All these factors are responsible for low investment in agricultural production activities. Mitigating the above aspects of crop sector productivity problems needs effective government strategy, actions and policy directions. A pragmatic agriculture policy leads to attain a breakthrough in agricultural productivity, which requires quantitative estimates of farmer's response behaviour in context of price and non-price variables. All previous studies on agricultural supply response in Bangladesh used time series data and classical regression analysis;

most use Nerlove's (1958) restrictive adaptive expectations or partial adjustment model(s). However, most economic time series are trended over time and regressions between trended series, may produce significant results with high R^2 , but may be produced spurious results (Granger and Newbold, 1974). This casts doubts on the validity of their result.

1.2 Objectives of the Study

The objectives of this study are to increase our understanding of the individual crop supply response through estimation of supply elasticity. There are two types of elasticities that have been used by policy makers: one is individual crop supply elasticity and another is aggregate supply elasticity of crops. More specifically, the aim is to choose a set of dynamic, theory based econometric models which are able to capture both short-run and long-run effects of price and non-price variable changes on major (rice and wheat) agriculture products in Bangladesh. Data determined, econometric modelling approach based on the error correction mechanism is used in this study. These results can be used for prediction and policy simulation under alternative assumed conditions. It is experienced from the previous studies that supply elasticities for individual crops are higher than for agriculture, particularly in the short-run. This is because crops can be obtained by reallocating variable factors across crops whereas aggregate response requires expansion of area (or fixed factors), technological change that are slower and relatively difficult to achieve than variable factor allocation (Mushtaq, 2000:6). The aim of this study is to investigate the acreage responses of the major agricultural products (rice and wheat) in Bangladesh during the period 1972-73 to 2003-04

1) To identify pertinent factors causing changes in area allocation of rice and wheat to the relevant variables which influenced supply response of rice estimate (elasticity) the long-run changes in terms of area yield, output, irrigated area nominal prices of rice and wheat.

2) To establish factors that explains long-run and short-run supply response of rice and wheat in Bangladesh.

3) To identify statistically relevant variables which influence supply response of rice and wheat in Bangladesh to gain insights to the effectiveness of price polices.

1.3 Methodology

The proposed study will collect data (both price and quantity) of major agricultural products and analyse using the statistical methods like cointegration and error correction method.

Empirical procedures are carried out in the following steps. *First*, annual data from 1972 to 2003 are obtained for the five time series. *Second,* each series is subjected to a set of unit root tests for the presence of unit roots among the data series and if present, then to differentiate the data to convert stationary series to avoid the spurious regression.

After using unit root tests to confirm that each series is *I (1)* process, Johansen maximum likelihood procedures are used to test for cointegration. Two conditions must be satisfied for integrated variables. *One* is at least two of the individual variables must be integrated of the same order and *another* is, a linear combination of the series should exist. Cointegration is introduced to test long-run equilibrium relationship(s) among the series. Since variables are cointegrated it provides an error correction model. The Error Correction Modelling (ECM) can be used as a unified empirical and theoretical framework for the analysis of the both short-run and long-run behaviour of the variables. The technical aspects of these procedures are described in detail in econometric methodology chapter.

1.4 Sources of Data

All econometric estimation in this study will be carried out on annual time series data available mostly from the publication of the Bangladesh Bureau of Statistics (BBS). However some of the latest figure on production and acreage will be collected from the Department of Agriculture Marketing, (DAM) Ministry of Agriculture and Bangladesh Agriculture Research Council (BARC).

1.5 Scientific Interest of the Study

The country is now on the threshold of attaining self-sufficiency in food grain production. But still instability of agricultural production and low price received by the farmers are the regular picture of Bangladesh agriculture sector. There are some economic and non-economic factors involved for this picture. But major concern is ineffectiveness of Bangladesh agriculture pricing policy and lack of proper plantings decision is the fundamental cause for instability of production and prices. Commercialization and effective pricing policy are pre-requisite conditions for long-run balance growth of agriculture production, which can only assure supply-demand balance of food grain. Following this perspectives it is very crucial issue to quantify accurately exogenous and endogenous factors involved with supply response of crops to meet the future demand for food grain.

The potential findings of this study can be vitalised for the following specific purposes:

a. To formulate a pragmatic agriculture pricing policy this is lever rest of the economy.

b. To help the policy makers to accurately forecast main agricultural product plantings decisions.

c. To understand the knowledge of supply response that can help planners to achieve the production target such as for five years plan.

The potential findings of this study will produce more accurate results than any other previous study on supply response in Bangladesh, because the study uses methodologically developed technique and analytical tools to avoid possible spurious regression results. In addition the study covers relatively big sample size which is appropriate for time series analysis.

1.6 Organization of the Study

This study is organized into nine chapters. Chapter one is introductory, that provides a preliminary sketch of the entire study.

Chapter two provides background information of the Bangladesh agriculture sector with a view to supply side of the economy. It discusses the structure and characteristics of the Bangladesh agriculture including cropping calendars, crop production policy etc. It also explores pertinent factors of crop output supply. Finally, this chapter provides agriculture products pricing policy both input and output perspective.

Chapter three is constructed on the basis of theoretical aspects of the supply response beginning with basic law of supply response. It represents the determinant factors of supply elasticity. This chapter discusses also the role of non-price variables including risk and uncertainty in agriculture supply response analysis. The end of this chapter provides critically the applicability of econometric models of supply response.

Empirical supply response studies at national and international level are reviewed in *Chapter four*.

Chapter five provides an elaborations discussion about econometric methodology of time series analysis is presented in chapter five. This chapter provides the empirical techniques used in supply response analysis. At the beginning, the researcher explains concepts of stationarity and unit root tests. The concept of cointegration is discussed with the approaches for testing for cointegration. It also discusses Error Correction Model (ECM) and linking between cointegration and ECM.

Chapter six is concerned with time series data of rice and wheat performing at national level for the period of 1972-2003. The researcher delineates change in acreage, output, yield and prices of crops for rice and wheat including irrigated area.

Chapter seven states that unit root testing procedure discussed in methodology chapter five and present the results. It begins with an informal graphical analysis of each data series. Unit root results are presented in tabular form using the Dickey-Fuller test.

Chapter eight presents the results of cointegration. The short-run and long-run acreage elasticities are estimated for each crop. It examines and explains these results.

Chapter nine provides a summary of the study. It draws some conclusions and indicates some policy guidelines. Some limitations of the study are mentioned at the end of the chapter.

Appendix 1.1: Total Rice, Wheat and Total Food Grain Production: 1990-1991 to 2002-2003

Year	Rice			Wheat			Total		
	Acre	Production	Yield	Acre	Production	Yield	Acre	Production.	Yield
90-91	25786	17852	0.69	1480	1004	0.68	27266	18856	0.69
91-92	25314	18272	0.72	1420	1065	0.75	26734	19337	0.72
92-93	25753	18342	0.73	1574	1176	0.75	26727	19518	0.73
93-94	24483	18041	0.74	1520	1131	0.74	26003	19172	0.74
94-95	24517	16833	0.69	1580	1245	0.79	26097	18078	0.69
95-96	24567	17687	0.72	1732	1369	0.79	26299	19056	0.72
96-97	25210	18883	0.75	1749	1454	0.83	26959	20337	0.75
97-98	25359	18862	0.74	1988	1803	0.91	27347	20665	0.76
98-99	24996	19905	0.80	2180	1908	0.88	27176	21813	0.80
99-00	26460	23066	0.87	2057	1840	0.89	28517	24906	0.87
00-01	26679	25085	0.94	1909	1673	0.88	28588	26758	0.94
01-02	26343	24300	0.92	1833	1606	0.88	28176	25906	0.92
02-03	26615	25187	0.95	1746	1507	0.86	28361	26694	0.94

Note: ('000 acres, '000 tonnes)

Source: Bangladesh Economic Review, 2004

Appendix 1.2: Aus, Aman and Boro Production: 1990-1991 to 2002-2003

Year	Aus			Aman			Boro		
	Acre	Production	Yield	Acre	Production	Yield	Acre	Production	Yield
90-91	5216	2328	0.45	14273	9167	0.64	6297	6357	1.01
91-92	4735	2199	0.46	14067	9269	0.66	6512	6804	1.04
92-93	4288	2075	0.48	14442	9680	0.67	6423	6587	1.03
93-94	4076	1850	0.45	14029	9419	0.67	6378	6772	1.06
94-95	4111	1791	0.44	13824	8504	0.62	6582	6538	0.99
95-96	3810	1676	0.44	13953	8790	0.63	6804	7221	1.06
96-97	3935	1871	0.48	14399	9552	0.66	6876	7460	1.08
97-98	3868	1875	0.48	14353	8850	0.62	7138	8137	1.14
98-99	3519	1617	0.46	12762	7736	0.61	8715	10552	1.21
99-00	3339	1734	0.52	14097	10305	0.73	9024	11027	1.22
00-01	3274	1916	0.59	14110	11249	0.80	9295	11920	1.28
01-02	3069	1808	0.59	13955	10726	0.77	9319	11766	1.26
02-03	3073	1850	0.60	14041	11115	0.79	9501	12222	1.29

Note: ('000 acres, '000 tonnes)

Source: Bangladesh Economic Review, 2004

Chapter 2
An Overview of Bangladesh Agriculture in Context of Supply Response

2.1 Introduction

Bangladesh is an agro-based developing country. Since its independence in 1971, the country is striving hard for rapid development of its economy. In all respects, the economic development is basically based on agriculture. It is often argued that the future development of the country depends particularly on the development and proper management of the agriculture sector. More specifically the food problem is most crucial aspect of economic development from political point of view. It bears upon the rate and structure of economic growth, rate of inflation, poverty and nutrition, and the balance of trade and government's fiscal position. The contribution of agriculture sector to Gross Domestic Product (GDP) is 19.11 percent in 2005 (Economic Review, 2006). In agriculture sector, the crop-sub-sector dominates with 14.32 percent in GDP of which rice alone contributes about 53 percent. In Bangladesh, although 63 percent of the labour force is directly engaged in agriculture and 78 percent of total crop is devoted to rice production, the country has still shortage of food grains. It is needed to mention here that the total food grains import by private sector in financial year 2005-06 is 25.62 lakh metric tonnes. Bangladesh government receive 1.94 lakh metric tonnes of food grains as food aid in financial year 2005-06 (Bangladesh Economic Review, 2006).

Mitigating food deficit for the vast population of this country the government has to import food grain from other countries through national and international agencies every year. A sizeable amount of the export earnings is spent for this purpose. This is mainly due to low productivity in rice production. Among the rice producing countries in Asia, Bangladesh occupies one of the lowest positions in rice production per acre (FAO, 1984). The sluggish growth in agriculture is mainly responsible for the stagnation of the economy. Over the last three decades the agricultural value added could not keep pace with the population growth (Bangladesh Bureau of Statistics, 2002). In a country like Bangladesh the growth of non-agriculture sectors is dependent on the growth of agriculture sector. The raw materials needed for the growth of non-agriculture sectors largely come out from the agriculture sector. So the poor performance in agriculture sector hinders the growth of non-agriculture sectors. This is one of the major causes of overall stagnancy of the agriculture sector in Bangladesh economy.

It is a prime concern to enhance the growth of rice production through increasing land productivity to meet the increasing food demand for the vast population of the country .As the country has serious land constraints, significant differences in rice productivity among the different regions are also barriers to the production growth (Hossain, 1990; Hossain and Ahmed, 1989). Many steps to enhance the growth are being taken from the part of the government and non-Government agencies since the dependence of the country. For future planning it is necessary to forecast accurately through time series analysis in context of supply aspects of rice and wheat. To reveal the supply pattern and to make best forecasts of rice and wheat major products in Bangladesh by appropriate time series models

2.2 Major Constraints and Opportunities in Bangladesh Agriculture

The following opportunity and constraints in agriculture sector have been taken into consideration with a view to formulate a national agriculture policy;

Opportunities

- Agriculture sector is the single largest contributor to GDP
- Crop production system is highly labour intensive and there is an abundance of labour supply in the country.
- Favourable natural environment generally exists throughout the year for crop production.
- Wide range of bio-diversity exists for different corps.
- Different crops and agricultural commodities are the main sources of nutrition, including protein, minerals and vitamins.
- Agricultural commodities have comparatively higher value added than non-agricultural commodities.

Constraints

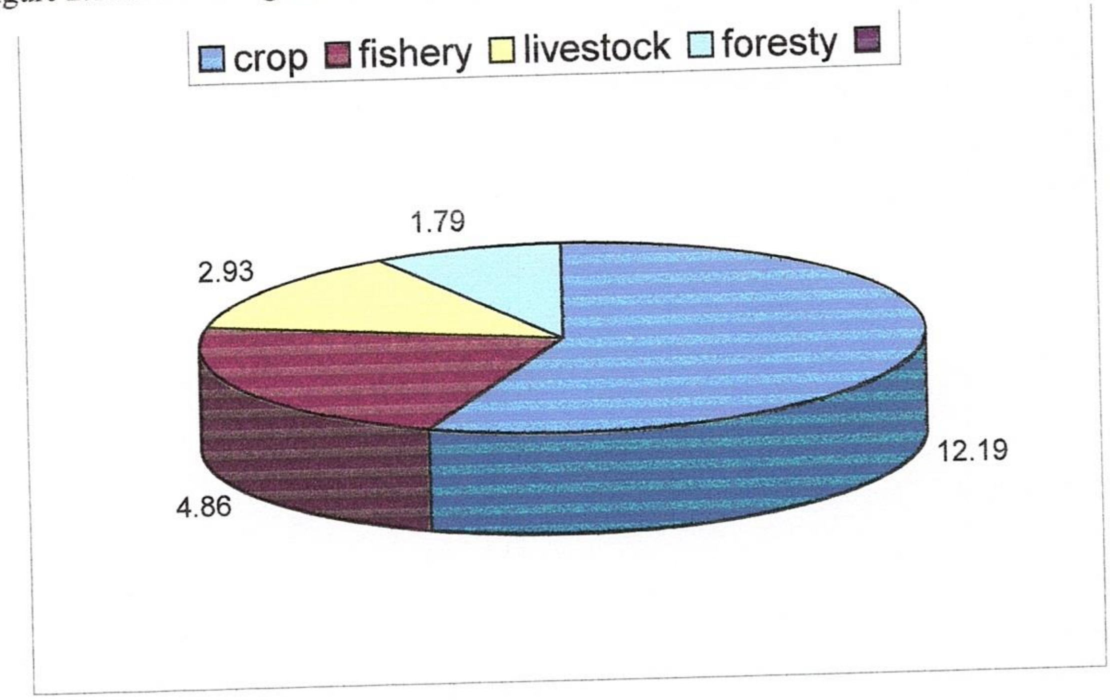
- Agriculture is dependant on the vagaries of nature and is risky.
- Availability of cultivable land is decreasing.
- Lack of proper land use planning.
- Widespread poverty among the population engaged in agriculture.
- Lack of required capital for agricultural activities.
- Agricultural commodities are rapidly perishable and post harvest losses are too high.

- Inadequate of appropriate technology considering farmers' socio-economic conditions.
- Uncertainty of fair price of agricultural commodities due to underdeveloped marketing system.
- Decreasing yields of different crops due to slow expansion of modern technology as well as unplanned use of soil and water.
- Inadequate use of improved seeds, fertilizers, and other inputs.

2.3 Structure of Bangladesh Agriculture

Bangladesh agriculture is the tiger point of all economic activity. Harvesting period and bumper production are the two key factors for generating economic activity. Over the last three decades contribution of agriculture to GDP is declining. Expansion of garments, manufacturing and service sectors and overall low growth of agriculture sector are the vital factors of declining trend of agriculture-GDP ratio in financial year 2005-06, the combined contribution of all sub-sectors of agriculture (Crop, livestock, Forestry and Fisheries) to GDP is 21.77 percent of this, the contribution of fisheries sector is 4.86 percent. Figure 2.1 shows the share of agriculture sub-sectors in GDP. The crop sub-sector alone is projected to contribute 12.19 percent to Gross Domestic Product (GDP) of the total labour force in Bangladesh, 51.7 percent is engaged in agriculture (BBS, labour force survey, 2002-03).

Figure 2.1: Share of Agriculture Sub-sectors in GDP in 2005-06



2.4 Characteristics of Bangladesh's Agriculture

Bangladesh is inherently a dualistic economy with an expanding industrial sector and a dominant subsistence agriculture sector. Agriculture is the mainstay in terms of its share to GDP and employment. This however, has declined over the years because of high population growth, adverse land man ratio. Because of high population, non-agriculture land use has increased, resulting in only 0.14 acre of agricultural land per person (Karim and Iqbal, 2001).

Bangladesh agriculture is now approaching transitional trend. Transitional in the sense that commercialization of agricultural is increasing day by day. Due to competitiveness and technological adoption in agriculture, commercial motive of production are the recent trend of Bangladesh agriculture.

2.4.1 Subsistence Level of Production

Overall agriculture production is still subsistence in nature. Agriculture production in Bangladesh is based upon small family farms. Its resources are limited to several fragmented plots of land, family labour, some rudimentary tools and a few cattle. Amongst these, fixed inputs are land, bullock power tools and machinery.

The major crops grown in Bangladesh are rice, wheat, Jute, sugarcane and tobacco. The main food grains or cereals are paddy, job, and barely. These crops are grown almost all over the country. The cereals are constituted about 78.32 percent of the total cropped area (Agriculture census, 1996). Among the cereals paddy is the most dominant crop. It covered about 20.83 million acres constituting 92.75 percent of the cereals area. Wheat occupies the second place cultivating in area of 1.52 millions acres constituting 6.79 percent of the cereals area. Other cereals were covered in of area a 57 thousands acres constituting only 0.26 percent of the cereals area.

According to '1996' census, major cereals i.e., paddy and wheat account for 99 percent of the total area of cereals. Among the major cereals paddy occupies about 93.19 percent of the total under cereals area. Table 2.1 shows area under major cereals by varieties in Bangladesh

Table 2.1: Area under Major Cereals by Varieties in Bangladesh (Area in acre)

Items	Total	Percent
Major cereals	22355067	100
Total paddy	20833078	93.19
Aus	4148615	18.56
Aman	10547646	47.18
Boro	6136817	27.45
Wheat	1521989	6.81

Source: Census of Agriculture, 1996.

Hence the economy is often characterised as a rice economy. Despite its overall dominance, rice production is still subsistence in nature. Only large farm households, and occasionally, during harvest seasons, medium farm households, are able to sell their surplus cereal products in the market (Hossain, 1995:16). In this context Ahmed (1981) mentioned that around 77 percent of the gross marketable surplus of rice comes from only 15 percent of the households.

2.4.2 Farm and Non-farm Employment

The rural farm households organizing the whole operation of agriculture activities mostly do cultivation of farm area in Bangladesh. The farm holdings are the households, which operate cultivated areas of 0.05 acres or above. The households operating cultivated area up to 0.045 acres considered as non-farm households. They have minor participation in cropping and agricultural activities.

According to 1996' census the total number of households in rural areas in Bangladesh is 17.83 million. Out of the total households of 66.18 percent is accounted for farm holdings and 33.82 percent for non-farm households. The distribution of total farm holdings among small, medium and large groups was 79.87 percent, 17.61 and 2.52 percent respectively. Table 2.2 shows number of households classified by non-farm and farm households (area in acres).

Table 2.2: Number of Households Classified by Non-farm and Farm Households (Area in acres)

Type	1983-84		1996	
	Area	percent	Area	percent
Households all	23019885	100	20484561	100
Non-farm up to 0.04 acre	341421	1.48	527417	2.57
Farm total	22678464	98.52	19957144	97.43
Small 0.05-2.49 acres	6573290	28.98	8218951	41.18
Medium (2.5-7.49) acres	10226402	45.09	8281741	41.50
Large (7.50 and above) acres	5878772	25.92	3456452	17.32

Source: Agriculture Census, 1996

About 80 percent farm holdings occupies only 41 percent of farm area where as 17.52 percent and 2.52 percent farm households occupies 41.50 percent and 17.32 percent farm area respectively. So concentration of land area in few farmers or conversely a large number of farmers operates a lesser area of land. According to 1996 censuses the total number of farm population is about 65.88 million and 11.80 million labours are employed. About 1.38 million is permanent labours as well as 17.32 million temporary labours performing in labour force frameworks.

Agriculture labour means those households, which (or who) mainly earn their livelihood by working in farms of other households for wages in cash or kind. They are mainly landless. In rural Bangladesh 12.59 percent households have no operated area. About fifty seven percent (57.19) households have no cultivated area. In recent years increasing population pressure on land and limited absorptive capacity of agriculture has forced a lot of agriculture labours to take up non-farm activities. Hossain (1995) mentioned agricultural labour might have one or more subsidiary (non-farm) economic activities like rearing of bovine animals, sheep goat, and poultry and having cottage industry. A major portion of agriculture labours is engaged with rural transport.

2.4.3 Land Ownership and Tenure Pattern

Out of the total land area of the country, rural households (HH) own 20.33 millions of land. It is evident from the 1996' census that 10.18 percent households owned no land and the residual 89.82 percent household owns land. The data related to the ownership of land of different categories of households for the rural area are shown in table 2.3.

Table 2.3: Households Reporting Ownership and Without Ownership of Land-1996

Categories	All HH	Percent	HH owing land	Percent	HH owing no land	Percent
Total HH	17828168	100	16013597	100	1814571	100
Group-1	162229	0.91	99005	0.62	63224	3.48
Group-2	5003042	28.06	3741455	23.36	1261587	69.53
Group-3	5191979	29.12	4889884	30.54	302095	16.65
Group-4	2494606	13.99	2397918	14.97	96688	5.33
Group-5	49769326	27.91	4885338	30.51	90988	5.01

Source: Agriculture Census, 1996

The five broad groups of households (HH) owning land and owning no land as mentioned in Table 2.3 are categorized as follows:

Group 1 : Households having no homestead area.

Group 2 : Households with homestead area but no cultivated area.

Group 3 : Households with homestead area and cultivated land up to 0.5 acre.

Group 4 : Households with homestead area and cultivated land from 0.51 to 1.00 acre.

Group 5 : Households with homestead area and cultivated land more than 1.00 acre.

It is observed from agriculture census 1996 that in the rural area, 89.82 percent of total households owned land and 10.18 percent of total households does not possess any land. Out of the total households owning land, 30.54 percent is in the Group–3 (households with homestead area and cultivated land up to 0.50 acre). It follows by 30.51 percent in the Group-5. The households without ownership (69.53 percent) are mainly concentrated in the Group-2 (households with homestead area but no cultivated land).

It is seen from the agriculture census 1996 that only 20 percent of total ownership of land is distributed among 66 percent of total households while the ownership of the remaining area, 80 percent is occupied by about 34 percent of total households. This indicates (Lorenz index about 0.59) that the degree of inequality of owned land is also high and the major portion of the owned area is occupied by few numbers of households.

2.4.4 Production Technology

As Bangladesh agriculture is traditionally a subsistence sector, it has been operating with Draught Animal Power (DAP) for various farm activities until early seventies. Traditional agricultural capital consists mainly of ploughs, bullocks, and homemade irrigation implements. However, since the mid seventies, Bangladesh of agriculture has undergone some adoption to the new seed-fertilizer-irrigation technology. (Hossain, 1995:19).Green revolution technology is the major technological breakthrough in agricultural history of Bangladesh. Over the last three decades (since early 1980s), the national policies have been directed towards transforming agriculture through rapid technological progress. Development programs have undertaken to diffuse modern varieties of rice and wheat with corresponding support in the provision of modern inputs, such as, chemical fertilizer, pesticides, irrigation, equipments, institutional credit, product procurement, storage and market facilities (Rahman and Karim, 1999).

Use of mechanical sources of power has gradually been increasing. Due to excessive sub-divisions and fragmentation of holdings, small farm size and capital constraints, complete mechanization is a time consuming matter in Bangladesh. Despite these constraints, it is realized that major portion of farmers in Bangladesh has mechanized their farming activities partially. They adopted and used different combinations of mechanical devices, such as mechanical irrigation, power tiller and tractor sprayers and threshes in their farming activities.

The Agriculture sector of Bangladesh has made remarkable progress in the 20th century. Since independence in 1971, agriculture sector has been grown over time. There is tremendous technological development in the 20th century. Until 2000, Bangladesh releases more than 50 modern varieties/hybrids of rice and more than 20 varieties of wheat. Improved varietals technologies are complemented with better crop husbandry practices, efficient utilization of fertilizer and irrigation, and pest management methods. Modern varieties and other inputs, production technologies and knowledge are disseminating to farmers' field through extension services and other public and private agencies.

Table 2.4 shows changes over the period of 1983-84 to 1996-97 in the uses of fertilizer and irrigated area.

Table 2.4: Changes over the Period of 1983-84 to 1996-97 in the Uses of Fertilizer and Irrigated Area

Parameters	1983-84	1996/97	Change over 83-84 to 96
Irrigated area (ha)	1620938	3762514	132.12
Farm holdings use of fertilizer (m.ton.)	6176100	9782685	58.40

Source: Agriculture Census, 1996;

Note: Table uses hectare as a unit of area.

As a result, total production level of food grain is increased from 12.14 million metric tonnes in 1973-74 to 26.24 million in 1983-84. It leads to food production is more than double in 2000-01 than that of 1973-74 (Deb, Billah and Das, 2004).

2.4.5 Landlessness and Marginalization of Landholdings

Landlessness is a major concern issue in rural economy of Bangladesh. Over the last three decades, high population, non-agricultural land use and poverty in rural areas increased landlessness and led to marginalization of landholdings.

Table 2.5: Parameters to Measure Landlessness and Marginalization of Land Holdings

Parameters	1983-84	1996-97	Change over 83-84 to 96-97 (percent)
Absolute landless (000)	1198	1815	51.5
Average farm size (ha)	0.81	0.61	-24.7
Small farm (000) 0.02-1.008 ha	7066	9423	33.3

Source: BBS, agricultural census, 1983/84 and 97.

Note: Table uses hectare as a unit of area.

Table 2.5 shows that absolute landlessness increased to 51.5 percent over the period 1983-84 to 1996-97. It also shows estimated that average farm size decreased to 24.7 percent over the same period. These are the clear indication of rising trend of landlessness and marginalization of land holdings.

Table 2.6 shows percentage change of landless households by three categories over the period 1983-84 to 1996.

Table 2.6 Percentage of Landless Households by Category (Figures are in percentages)

Category of landless	Agricultural census 1983-84	Agricultural census 1996'
Percent of landless-1	8.67	10.18
Percent of landless-2	19.64	28.06
Percent of landless-3	28.21	29.12
Total	56.52	67.36

Note: Category-1: households having no owned area whatsoever;
Category-2: households with homestead area but no cultivated land;
Category-3: households with homestead area and cultivated land up-to 0.5 acre

Source: BBS, agricultural census, 1983-84 and 1997.

According to the 1983-84 agriculture census, landlessness under category–1 (households having no owned area whatsoever) was 8.67 percent which increased to 10.18 percent in 1996' census in the rural area of the country. Landlessness under category-2 (households with homestead area but no cultivated land) was 19.64 percent in 83-84, which increased to 28.06 percent in 1996 respectively. Landless under category-3 (households with homestead area and cultivated land up-to 0.5 acre) was 56.52 percent in 1983-84, which increased to 67.36 percent in 1996. According to the census data the landlessness under category-2 households has tremendously increased.

It is also observed from several studies that, a significant proportion of rural households are landless and that landlessness is increasing and small farmers in turn become landless.

2.4.6 Agro-climate and Natural Calamities

Weather condition is the crucial variable that affects agriculture in a subsistence economy as that of Bangladesh. Agro production cycles and cultivation in Bangladesh are subjected to annual draught and flooding, to periodic cyclones and to tidal waves. Availability of water for cultivation is extremely dependent on regional and season variations. Total annual rainfall of Bangladesh is one of the highest in the world. Mean annual rainfall varies from 1250 mm in the extreme west to over 5000 mm in the northeast region of the country, although mean annual rainfall over most part of the country ranges between 1500-3000 mm. Distribution of rainfall is highly seasonal. More than 85 percent of the total annual rainfall occurs between June-September, while the rest occur during October-November and partly between ends of March to end of May. December to mid March is almost rainless.

During the monsoon period the big rivers of the country rise to high levels and overflow much of the country that has a nearly flat topography. Flood is a regular phenomenon. Although farmers have adapted their farming practices to normal annual flooding, even in a normal year floods curtail crop production to a considerable extent (Hossain, 1995:25). However, during the long dry season, water levels of all rivers fall drastically and due to lack of rainfall it is impossible to sustain without irrigation.

2.4.7 Crop Seasons in Bangladesh

The country grows a wide variety of crops, which are broadly classified, according to seasons in which they are grown, into two groups: (a) Kharif and (b) Rabi crops.

Kharif crops are grown in the spring or the summer season and harvested in late summer or in early winter.

Rabi crops are sown in winter and harvested in the spring or early summer.

Table 2.7 provides a brief description of crops season in Bangladesh

Table 2.7: Time of Sowing, Transplanting, and Time of Harvesting of Different Crops (rice and wheat)

Crop	Time of sowing/transplanting	Time of harvest
1. Aus paddy		
a) Broad cast	Mid March to mid May	July to mid August
b) Transplant	Mid April to mid June	-do-
c) HYV	Mid March to mid April	-do-
2. Aman paddy		
a) Transplant	Mid June to mid August	mid November to mid January
b) Broad cast	March	-do-
c) HYV	Mid June to mid August	-do-
3. Boro paddy		
Local	Mid November to mid January	mid April to mid June
HYV	Mid December to mid February	mid April to mid June
4. Wheat time of sowing/transplanting time of harvest		
wheat	November to December	Mid March to mid May

2.5 Controlling Factors of Crops and Cropping Patterns

Bangladesh agriculture is traditionally subsistence in nature and family farm based. Before the advent of green revolution, crops and cropping pattern were determined mainly by land topography (in relation to flooding), soil permeability, soil moisture holding capacity, length of growing season, climate, socio-economic factors like farm size, draught power availability and financial resources etc. During the late 1960s and throughout the 1970s breakthrough in rice production technologies occurs which have set in the motion of the process of changes in land use, cropping intensity and cropping patterns (Karim and Iqbal, 2001: 71).

The factors which contribute to the change acting singly or in combination are:

- Availability of High–Yielding Modern Variety (MV) of rice and wheat, and other crops like oil seeds, sugarcane, potatoes, vegetables etc.
- Increase in use of chemical fertilizers.
- Improvements in cropping environments brought about by provisions of irrigation and drainage, implementation of Flood Control and Drainage (FCD) and Flood Control Drainage and Irrigation (FCDI) projects, erection of embankments, fall in general flood level particularly in the 'Ganga' and 'Brahmaputtra' flood plains. Also rapid expansion of irrigation facilities launches by the government in rural area in Bangladesh since 1980-81.
- Improvements in rural infrastructures, especially road communication and market outlets.
- Increasing population pressure (thus food needs)
- Education and increasing awareness of farmers.

The changes in crops and cropping patterns have resulted from new opportunities made available through improvements in credit facilities, marketing, input supply, extension services etc. Most changes, however, have resulted from high degree of complementarities between irrigation, fertilizer use and use of Modern Varieties (MV) seed since the mid of 1970s. However, irrigation has been the leading factor.

Cropping pattern in Bangladesh is multifarious and varied according to crops being grown, regions, soils and other factors. The major crops aman rice and jute are grown during the monsoon. Other crops such as Boro rice, potatoes, oilseeds, pulses and vegetables are mostly grown in the winter season. If irrigation is available, high yielding rice or wheat is grown.

A short description of cropping pattern and nature of land in Bangladesh are presented in table 2.8.

Table 2.8: Cropping Pattern and Nature of Land in Bangladesh

Cropping pattern	Estimated extent (percent)	Land type	Yield (t/ha)
1. boro-F -T. aman	22.2	HL, MHI, MH2	6.5-7.8
2. F-F-T.aman	13.4	HL, MHI, MH2.ML	3.3
3. boro-F-F	10.3	MH, ML, LL, VLL	3.7-4.1
4. F-T.aus-T.aman	5.8	HL, MH1, MH2	4.8-6.1
5. Rabi-ausT.aman	4.8	HL, MH1, MH2, ML	0.8+4.8
6. F-aus-T.aman	4.2	HL, MH1, MH2, ML	4.8
7. Rabi-F-T.aman	4.0	HL, MH1, MH2, ML	0.8+3.3
8. F-DW aman	3.4	ML, LL, VLL	1.5
9. Wheat-F-T.aman	3.2	HL, MH1, MH2, ML	1.5+3.3
10. Mustard-boro-F	2.5	MH, ML, LL	0.85+4.1
11. Rabi-DW aman	2.5	ML, LL	0.8+1.5
12. Rabi-aus-F	2.5	HL, MH, ML, LL	0.8+1.5
13. Rabi-jute-T.aman	2.3	HL, MH1, MH2, ML	0.8+1.8+3.3
14. Rabi-jute-F	1.7	HL, MH1, MH2	0.8+1.8
15. Rabi-mixB.aus+B.aman	0.8	ML, LL	0.8+1.6

Note: HL=High land. Above normal flood-level
MH1=medium high land. Land normally flooded up to 30cm deep.
MH2=medium highland 2. land normally flooded between 30 and 90cm deep.
ML=medium lowland. Land normally flooded between 90 and 180cm deep.
LL=low land. Land, which is normally, flooded between 180cm and 300cm deep
VLL=very lowland. Low normally flooded deeper than 300cm.

Author uses hectare as a unit of area.

Source: Elahi, et al (1999).

2.6 Crop Production Policy of Bangladesh Government

The production system of Bangladesh dominated by a single crop (i.e., rice) is neither scientific nor acceptable from the economic point of view. This characteristic indicates vulnerability of Bangladesh agriculture sector. Moreover, cropping culture is almost dependent on nature. However, considering the increasing demand for food grains and with a view to ensuring food security, production of rice constantly gets priority in the food grain production program in Bangladesh. At present rice covers 75 percent of cultivated land in Bangladesh. Area coverage by other crops is pulses 4.64 percent, wheat 3.92 percent, and jute 3.71 percent, and oil seeds 3.77 percent. To increase rice production Government of Bangladesh (GOB) has already taken supportive programs to rise per hectare yield through the use of modern technology and improved cultural practices along with the increased use of HYV seeds. Fallow cultivable land is only 4.14 percent. Currently, cropping intensity is around 185 percent. So Bangladesh has only possible option for increasing agricultural production through increase in the cropping intensity and yields simultaneously. In this respect, policies adopted by the government are

Bangladesh government has to take supportive programs for inter-cropping in a field instead of single cropping. Government has also taken appropriate measures in reducing the gap between potential yield and farmers' realized yield of different crops to raise the present level of production significantly.

Crop diversification is one of the major components of crop production policy. Under this program, expanding of wheat acreage efforts will continue to increase wheat production. But wheat production has been gradually decreasing since 1990-00. Decrease in wheat production is due to decrease in both productions by 16.9 percent and yield by 9.8 percent of wheat over 2000-01 to 2003-04 (Deb, Billah and Das, 2000:9).

Another regular picture is that aman crop is heavily damaged every year due to the inadequate soil moisture regime prevailing in draught affected areas. To combat this situation government has adopted the following polices:

- Supplementary irrigation has been ensured in severe and extremely severe draught affected areas.
- Location of specific suitable crops will be identified with respect to technological and economic parameters and appropriate strategies will be pursued for cultivating those corps.

2.7 Pertinent Issues of Crop Output Supply: Socio Economic Perspective

Self-sufficiency is very important in agriculture sector. Bangladesh is not an exception to that. Self-sufficiency is the key feature of Bangladesh's peasant at household farms. All agricultural activity is centred to self-sufficiency. If production is largely for the consumption of the operator family and few of the inputs are purchased, relative prices have little effect upon the firm under any circumstances. Production decisions will be based largely on resources owned or controlled (mostly land and labour), and consumption preferences (Johnson, 1969:252). Broadly speaking agricultural production in Bangladesh is based upon small family farms, and at family level it is prime concern to attain self-sufficiency in food grain. Fragmented plots of land, family labour, few rudimentary tools and a few cattle–are the common factors of production of Bangladesh agriculture. These facts reflect scarcity of resources specially land in comparison to demographic factors (Karim and Iqbal, 2001).

Land is the fixed factor, which is the principal determinant of crop output supply in Bangladesh agriculture. The peasants adjust their labour with land to attain a desired level of output. In Bangladesh land has been allocated, firstly to ensure self-sufficiency in crop output towards to attain food security at family levels. In this respect rice production is a crucial issue for family level food security. The land allocation decision is influenced by output requirements for subsistence and future production use, expected relative prices (the relative prices ratio is relevant), availability of different factor inputs and perceived risks in production. Once land is allocated, the intensity of factor use is decided by the prevailing factor prices (input-input relationship is established). As discussed before, sub-optimal levels of resources allocation i.e., land, labour and fertilizer may prevail due to prevalence of risks as well as for certain tenure arrangements particularly share-cropping. However, the supply of food crop products is largely dictated by family requirements rather than market. Cash crops are mostly grown for market[1]. Farm size varies in response to the extent of possession of production resources. As an individual, the farmer cannot influence the market price of his product. So market production strategy has to adjust productive resources to achieve a desired output level. However, crop production activities in agriculture broadly satisfy the twin objects of maintaining subsistence as well as operating economically for long–run survival.

Farmers produce agricultural product with two objectives. One is household consumption and partly for market, as peasant farms who are fundamentally characterized by partial engagement in markets which function with some imperfection.

Farmers of Bangladesh are concerned about commodity prices compared to intra-agricultural commodity prices though their production approach is subsistence oriented. Despite all these things it is an inherent phenomenon of producer to maximize profit by selling commodities. In these contexts, it is needed to say that the

[1] In Bangladesh the major cash crops are jute, sugarcane, tobacco and potato. Jute and sugarcane give cash supports to the farmers, though jute is decreasing trend in production since last twenty years.

rural market of Bangladesh is almost imperfect as well as poor infrastructure. So, profit and market structure are general determinant factors of output supply in Bangladesh. Farmers' expectations of future relative prices play in shaping their decisions as to how many acres are to devote to each crop. Expectation about the future price of a product may affect the current supply. The expectation of higher price for rice may induce farmers to withhold some products from their current harvest and it reduces the current supply of the particular season in market.

Changes in prices of other products that can be substituted in production may change the supply for a given product. In recent time, due to crop diversification trend the farmers shift some portion of land from rice to profit making products such as vegetables, fish, watermelon, etc. This trend varies region to region in Bangladesh. All these related studies suggest that farmers respond very high to price of substitute crop in planning their acreage. These phenomena are observed frequently in the case of joint products in agriculture sector.

Marginal cost is another determining factor for output supply. According to production theory, marginal cost and output supply are synonymous, any reduction in marginal cost will increase supply, and any increase in marginal cost will decrease supply (Horlod, 1980:152). So, any changes in the prices of inputs (seed, fertilizer, pesticides, etc) will have the negative effects on output supply.

Two main factors responsible for change in supply response are technology and change in input prices. The adoption of technologies to farm production creates lower costs per unit of output and act as an incentive to the individual farmers to increase production. Non-farm factor markets often influence changes in the prices of factors concerned with agricultural production (Snodgrass and Wallace, 1964:244) Input prices are known at time when major farm production decisions are taken. Therefore, expected product price is the real concern in using productive resources. In such a situation, when a product price variable is used as a ratio to price (s) of competing crops for deflation, that will take into account the profitability of supplying a particular crop product with respect to competing crops. The price of the concerned crop relative to competing crop (s) as an explanatory variable in area response function allows the capture of substitutability between and among productive resources (Alam, 92:72). The change in the price ratio between input and output leads to the position of that particular product in economic optimality. Therefore, product price deflated by an index of relevant inputs prices would be desirable for the profit maximizing farm. As output price changes have to be examined in terms of changes in factor prices that affect the marginal cost curve of the involved farms. But it is very difficult to compute of input prices in production process because in the case of Bangladesh, most of the inputs / factors are home supplied in agriculture sector. In this case, they generally don't maintain input costing. So, information is not available. In addition, in time series phenomena information on inputs prices are not available. It is needed to mention here that information about input prices is not available at Bangladesh Bureau of Statistics (BBS) before 1980. However, where there is access to labour wage information, the product price variable may be used as a ratio of the costs of per acre labour wages. Resources are limited and have alternative uses to increase output of a crop provided only by effective uses of resources. So, it is very much reasonable to use the price variable as relative term rather than an absolute term where resources have a distinct alternative use. It is observed that, in rural Bangladesh product prices vary pre-harvest, harvest and post-harvest periods. Prices remain lowest at the immediate after harvest period and significant amount of products are sold at this period. There are two pragmatic reasons for lower prices of products at harvest period in rural Bangladesh. *Firstly*, small farmers are not economically solvent in rural Bangladesh. *Secondly*, storing facility is not available in rural area, so they bound to sell their major portion of products just after harvesting. Moreover, public financial support policy does not meet small farmers need for livelihood. But few farmers can hold crop output for sale until the peak arrives. Due to poor circumstances of farmers are bound to sell lion portion of crop at immediate post-harvest price. For this reality immediate post-harvest price is more relevant factor for area allocation decisions in rural Bangladesh.

While additional labour has a positive marginal product, it is very small with contrast technology and the usual quantities of other inputs in Bangladesh. About 65 percent farmers in Bangladesh are marginal farmers. They have no additional resources or liquid money to buy inputs instantly. In this context they are highly dependent on borrowing money from relatives, neighbours and Mohajon[2]. Lack of ability to purchasing capacity to inputs, simultaneously high costing of agricultural inputs, farmers can not use inputs in production process in due time. As a result, low productivity is a common phenomenon.

The preponderance of small farms in Bangladesh agriculture has made credit dependence a critical element in agricultural production activity. The need for credit extends from maintenance, operational as well as investment activity involving

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[2] Mohajon is locally called name who acts as money lender with high interest rate in rural Bangladesh.

agriculture. This scene is to be comprehended in the context of total absence of any organized financial institutions in the rural areas until recently.

Bangladesh agriculture is highly dependent on rainfall for soil moisture and this is a very crucial risk factor in agriculture production. Cropping cycles are attuned to rainfall and climatic patterns. Rainfall is mostly concentrated in the monsoon period, which starts in July and lasts until October. This period accounts for 80 percent of total rainfall. The average annual rainfall varies from 1194 millimetres to 3465 millimetres (BBS, 2001). Winter has the driest months, and begins in November and ends in February. Crops grown in winter are called Rabi crops and crops grown in pre-monsoon and monsoon periods are called Kharif crops. Production of rabi crops and pre-monsoon crops depends on soil moisture and availability of water through precipitation and access to irrigation. The irrigated area for aus and aman crop is appropriate in most cases for high yielding variety seeds. Irrigated agriculture is mostly confined to the winter season where there is access to water sources. The crop grown in other seasons gamble on the vagaries of nature. There is also a problem of inadequate or excess rainfall, which is related to drought or flooding. There are problems of cyclones, fluctuations of temperature that lead to farming unpredictable.

The production process in agriculture is relatively long. In the short-run, the supply of agricultural products tends to be very inelastic for three reasons. *Firstly*, high costs of production are fixed in the short term so that the scope for curtailing costs by reducing production is severely restricted. *Secondly*, because of their immobility, the opportunity

In short, the main biological factors affecting the elasticity of supply of agricultural products are length of the production cycle, the constraints imposed by diminishing returns on economic utilization of feeding stuffs, fertilizers and other inputs, seasonability of supply perishibility of products which because of uneconomic storage costs, limit the scope for holding stocks (Hill, and Ingersent, 1977:63).

In time series analysis technological aspects are important determining factor in crop output supply phenomena. In context of Bangladesh improved land preparation to permit adequate root development is possible with mechanized cultivation, which is out of necessity due to acute shortage of draught animals (Rahman, Haque and Ahmad, 1984:260). Due to changes of technology, production processes have massive impact on output supply. Appropriate adoption of technology leads to higher yield rate and reduce per unit cost of production. Therefore, yield elasticity to price changes the responses of effects of changing technology in production. For a particular crop, positive technological effects attract new land due to high yield rate in the case of output maximizing motive. But subsistence level farmers produce more than one product for family consumption. In that case, the motive is to minimize cost and risk, so technological aspect does not play significant role in rural Bangladesh at least small family farming.

In addition, where 85 percent are marginal or subsistence farmers there may be an objective of attaining a certain level of cash income from each kind of crop enterprises. Finally, it is observed that technological change has little impact on land allocation as well as output supply especially in the case of subsistence level farmers in Bangladesh.

A number of basic factors have been considered in appraising the output supply of household farmers at the recent time in Bangladesh. *At the individual level, factors influencing decision making for supply of crop products depend on the respective location of product for the subsistence requirements for food grain, respective product prices, available water supply, and price of competitive crops when the question of enterprise choice is concerned. All these factors affect output supply of individual farmers.* In the case of large farming the level of expected yields is conditioned by the state of technology, the risk concerning yield and prices, input price and availability. in this connection price support policy by the government after all demand for that product in domestic and international market are major factors for crop output supply. It is needed to mention here that fluctuation in output supply may not be seen as a result not just for price but for non-price variable. However, changes in supply to output price changes are not instantaneous. Farmers look at any changes as transitory or permanent, even when price changes are considered somewhat permanent, it takes time for adjustment of resource allocation. In this context, *lag length* or adjustment period is also shaped by social, institutional, cultural and market forces.

In summary, it may be concluded that the supply decision of small farmers will be primarily by the need to meet subsistence requirements of the family, and in this endeavourer, farmers will try to minimize risks since cost of crop failure would be starvation for the family. On the other hand, large farmers produce primarily for the market rather than home consumption. Hence production or supply decisions will be considerably influenced by the desire to maximize profits. It is therefore expected that decision pertaining to output of food grains would be affected by relative price movements in the case of large farmers but not in case of the small farm.

2.8 Agriculture Pricing Policy: Input and Output Perspective

After the independence of Bangladesh, most of the organized activities in Bangladesh economy are owned and operated by the public sector. Various public agencies, such as state of ownership is partly rooted in the past policy regimes and is partly de-facto outcome due to absence of the previous entrepreneurs and institutions. Since the late 1970s, reforms in the food and agriculture sector are initiated to gradually limit the space of the public sector. These reforms remained at sectoral level, until being packaged under Structural Adjustment Policies (SAP) during the second half of the 1980s. While policy reforms continued into the 1990s, some of the major reforms in the agricultural input markets come about in the 1980's. Two important elements of these reforms are perceived to include reduction of subsidy, and increasing participations of private sector in the procurement and distributions of inputs. From such perspective, effects of reforms on the crop sector profitability in particular, are expected to be mixed. Reduction of subsidy is expected to reduce farmers' profit (net income) and adversely affect crop sector growth. On the contrary, increased competition in the input market due to private sector participation is expected to lower input prices and raise farm level profitability (Zohir, 2001:1)

The intention of this section is to explore the relative roles of state and market on agriculture pricing and trading. Agricultural pricing policies have become one of the liveliest areas of controversy in the literature on state adjustment policies. The following section has been made on the basis of food grains pricing policy in context of output supply.

After the existence of Bangladesh and up to the early 1980s, Bangladesh leads its food grain pricing policy to provide low and stable prices to consumers. It is observed that procurement prices are below market prices in four out of seven years up to 1979-80. At that time movement of food grains is restricted, and urban consumers are supplied with the 'wage good' at subsidized prices through an elaborated system.

On the other hand to compensate producers for low output prices, input subsidies (fertilizer, irrigation, etc.) are provided. Subsidies on consumer food prices and agricultural input create double burden and start to impose a significant burden on budgetary resources of the government by the end of the 1970's . At the beginning of the 1980s, government initiated to reform price policy due to budgetary burden and external forces. In this view the, government under take price policy reforms under guidance of Structural Adjustment Policies (SAP). Major reforms were:

- Withdrawal of food subsidies in the urban rationing system and instead targeting food subsidies to specific groups, e.g., rural poor through a rural (palli) rationing system; counteracting unexpected and large food grain price swings through open market sales in specific urban areas (which could in principle reduce the fiscal cost of food subsidies);
- Withdrawal of agricultural input subsidies;
- Privatization of import, management and distribution of fertilizer and irrigation equipment; and

- Changing the output price policy to reflect "incentive" prices rather than procurement prices.

An inter-ministerial committee introduced a uniform procurement price for particular crop for the entire country. This price was made on the basis of average production cost plus a 15 percent mark-up. The government's definition of "incentive" price was average cost of production plus a 10 percent mark-up.

Usually procurement prices announces in all years for the major crop, i.e., aman. For boro, i.e., the dry season modern variety rice, it has been announced since the 1982-83 crop year. Procurement price of wheat has announced since 1975-76. Bangladesh government announce procurement prices are made few weeks before launching of the programme. According to Zohir (1995) it is observed that procured quantities are very small and in case of wheat grower, prices have been lower than procurement price without some exception. It is evident from related studies that government procurement has not influenced the determination of market prices of rice and wheat significantly (Planning Commission, 1989). But it is likely that grower's price would have been lower than observed market prices in the absence of public procurement.

It is quit evident that some major policy reforms came about during the 1980's. More important among these are:

a) Deregulation of fertilizer prices with private dealers collecting directly from the factories

b) Transfer of ownership of tube-wells from Bangladesh Agriculture Development Corporation (BADC) to private hands, (cooperatives, informal groups and individuals) and most importantly

c) Withdrawal of restriction that previously limits the choice of users. It is commonly perceived that the last set of policies liberalizing the restrictions on irrigation equipment and allowing private sector import has the most impact on the crop sector production in Bangladesh.

The 1990's experienced further liberalization, especially in the trade sector, having important implications for the crop production. The rural rationing is withdrawn in 1991; largely restricting public off takes of food grains through non-mortised channels and open market sales. Import of fertilizer by the private sector is allowed in 1992, with special credit support provided to the importers. During the same time, private sector participation in import of food grains is also opened up. The 1990's also marked by significant increase in mechanization of crop production, largely facilitates by the liberal policy towards importation of farm machinery and farm credit to support it (Zohir, 2001:17).These measures produce overall positive impacts on the overall crop supply situation in Bangladesh.

2.9 Conclusions

The aim of this chapter is to overview Bangladesh agriculture in context of supply side approach. This chapter highlights on supply side constraints of agricultural products. It covers the potential factors of output supply, government initiatives and supportive policy to enhance agricultural products. It also explores the output determining factors of agriculture products in Bangladesh on the basis of socio economic aspects. It is importantly said that supply decision of the medium and small farmers primarily by the need to meet subsistence requirements of the family, and in this endeavourer farmers will try to minimize risks since the cost of crop failure would be starvation for the family. Finally, it is therefore expected that decision pertaining to output of food grains would be affected by relative price movements in the case of large farmer but not in the case of small farms. We examine the relative roles of state and market on agriculture pricing and trading. Just after the independence of Bangladesh, most of the organized activities in Bangladesh economy are owned and operated by the public sector. Limited public agencies, such as, state of ownership is partly rooted in the past policy regimes and is partly de-facto outcome due to absence of the previous entrepreneurs and institutions. Since the late 1970s, reforms in the food and agriculture sector are initiated to gradually limit the space of the public sector. The aim of these initiatives is to overcome supply side constraints of agriculture sector. Because it is already identified that food problem in the country is viewed as supply oriented. In this context Bangladesh government takes various supportive policies like crop production policy, input support policy to increase overall production at national level.

Chapter 3
Review of Literature on Supply Response

3.1 Introduction

Though supply response is not a new issue in production economics, few research works on supply response have been done in Bangladesh. Literatures of the empirical works which have already been done are reviewed in this chapter. Most of the previous papers deal with the role of farmers' expectations of future relative prices that play in shaping their decisions as to how much acreage to devote to each crop. Although researchers and most of the previous workers in the field of supply response have concentrated on acreage decisions, most of the studies on supply response have been made on the basis of theoretical model followed by empirical analysis. Generally, theoretical models are constructed on agricultural supply response involved with two steps:

Firstly: to determine the basic objective of the production plant.

Secondly: to identify the determinants of supply by optimizing the production objective under certain constraints.

The concern of this chapter is to review relevant literature on agricultural supply in Bangladesh. Previous econometric studies have estimated rice and jute supply or area elasticities in Bangladesh (or East Pakistan), using alternative methodologies and sample period.[3] The following section reviews supply response in Bangladesh with particular reference to rice, wheat, and jute.

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[3] The econometric estimates of previous studies on supply elasticities in Bangladesh are presented in appendix 3.1.

3.2 Reviews on Previous Supply Response Studies

Hussain (1964) makes a study on price responsiveness of rice and jute area for the period of 1949-63. He uses simple linear equation, like, $A_t = a + bp_{t-1}$, where A_t is the rice acreage under both aus and aman in all of Bangladesh area, and p_{t-1} is the relative price of rice to jute in the preceding year (the relative price of aus rice is the average aus harvest price divided by the average jute harvest price). The elasticity of this function at the average price and acreage emerge as 0.04. He found that the variance is as low as 0.18 though the price coefficient is significant at one percent level. But when the equation is re-specified with the proportion of rice acreage in the total rice–jute area *(A/A+J)* as a function of the relative price of rice, it explained higher proportion of the variance 0.64. The price elasticity of rice acreage is calculated to be 0.03 on average. In all cases, the explanatory variable is the jute harvest price, divided by the aus harvest price, and in all cases, the price variable is significant.

Hussain estimates elasticity for jute by using a simple linear equation though it is comparable to other estimates, but one of the problems is that one cannot obtain any estimate of farmers' behavioural patterns on expected price and their level of adjustment if any, which are also considered important elements of farmers' responsiveness in the face of a changing decision environment. He used a single explanatory variable (price) to explain the variations in area.

In a later study, Hussain (1969) conducted an empirical studies of the hypothesis that farmers response to price declines under the influence of the growing constraint of subsistence farming. According to Hussain, in terms of area allocation decision pattern, farmers assuming those who only grow rice and jute on their land reidentified with five production possibilities of growing rice or jute for them depending on the prices and yields involved.

These are:

1) $P_j^* Y_j > P^*_{R1} Y_R$ jute specialisation

2) $P_j^* Y_j < P^*_{R2} Y_R$ rice specialisation

3) $P^*_{R2} Y_R P_j^* Yj < P^*_{R1} Y_{R,}$ price production to meet farm consumption by own produce and jute cultivation on the remaining land (subsistence farming).

4) $P_j^* Y_j = P^*_{R1} Y_R$ either case 1 or case 3

5) $P_j^* Y_j = P^*_{R2} Y_R$ either case 2 or case 3

Where, P_j^*= expected sales price of jute per unit of weight (tonnes).

P_{R1}^*= expected purchase price of rice per unit of weight (tonnes).

P_{R2}^*= expected sale price of rice per unit of weight (tonnes).

Y_j=yield of jute per unit of land (acre).

Y_R= yield of rice per unit of land (acre).

It is category (3) in which the constraint of subsistence farming arises basically from the minimum food required to survive and the economic advantage of producing food rather than buying it from market.

According to Hussain due to subsistence farming system Nerlovian price expectation or area adjustment model does not operate completely in Bangladesh, so farmers will not be able to adjust output to the desired level even in the long-run. This renders the coefficient of adjustments to be low.

Cummings (1974) has done a study on supply responsiveness of rich and Cash crop. It is another study on responsiveness of rice and jute is done by Cummings at the same period of Hussain (1949-68). This study estimates supply elasticities for several crops in Bangladesh through price expectation model. In order to avoid parameter problem within the Norlovian framework, he estimates specified equation for various values of the pressure of the population on land and the consequent increase in the subsistence cultivation of rice. The response of acreage to yield (yield deflated by the yield of rice in the adjustment model) is negative and significant which he cited in favour of the above proposition.

Cummings estimated regression fit is better than Hussain, though coefficient of price variable is less significant. He uses a maximum likelihood approach. In this study Cumming introduces acreage as the dependent variable, and price is deflated by a cost of living index, lagged area, index of rainfall preceding and during the sowing period and a trend variable are explanatory variables. One of the positive aspects in his model that he uses more than two explanatory variables for the specification, which his predecessors has not done before in Bangladesh; this partly help to overcome the problem of incorrect specification of the supply response model.

Ahmed (1977) conducts a study on food grain production, growth and related policies in context Bangladesh. His sample size is (1960-77) smaller in compare to other studies on supply response. He uses a price expectation model to measure the responsiveness of rice area as a whole. Due to small sample size, the regression equation has produced weak statistical fit. The estimated elasticities are low which is 0.33 in the long-run and 0.21 in the short-run. He discards the Nerlovian price expectations model because it works with normal expected prices and does not consider any variation. So, the Nerlovian model is not perfect for supply estimation. He uses Maximum Likelihood procedures for supply estimation.

It is needed to say that the above mentioned studies do not include dummy variables or external factors such as technical change and weather in estimation of supply responsiveness. Moreover, this study considers annual average prices, which are questionable on the ground of seasonality.

Hossain (1984) makes a supply response study on some selected agricultural crops in Bangladesh for the period of 1972-73 to 1982-83. Hossain makes an attempt to determine the degree of price responsiveness of aus, aman and boro rice, and also wheat, jute sugar cane, tobacco and potato. In this study Hossain use Cagan's adaptive expectations model and incorporate it into a partial adjustment model' as devised by Nerlove.

According to Hossain's estimation, output is a result of acreage planted and yield. That is, $Q = AY$, where Q, A and Y are output, acreage planted, and yield of the crop respectively. Acreage planted and yields obtained are both postulated to be functions of crop price that is as fallows:

$$E_{QP} = E_{AP} + E_{YP}$$

i.e., price elasticity of output = price elasticity of acreage + price elasticity of yield.

The relevant price that is considered in the output response function is the price of the crop in question deflated by the price of the competing, alternative crop and prices of inputs of production. The adaptive expectations model, as applied to acreage response, consists of two hypotheses. *First,* equilibrium or planted acreage is determined on the basis of expected (relative) price of crop. *Second,* in each period of production, acreage is partially adjusted in proportion to the difference between period's actual acreage and the long-run equilibrium acreage. A summary of the price elasticities of supply estimated by Hossain presented in Table 3.1,

Table 3.1: Estimated Price Elasticities of Supply

Crop	Acreage Elasticity		Yield Elasticity		Output Elasticity	
					Short- run	Long - run
Aus Rice	0.71	0.81	-	-	0.71	0.81
Aman Rice	0.05	0.12	-	-	0.05	0.12
Boro Rice	-	-	0.19	0.35	0.19	0.35
Wheat	-	-	-	-	-	-
Tobaco	0.28	0.49	0.07	0.23	0.35	0.72
Jute	0.48	0.60	-	-	0.48	0.60
Sugarcane	-	-	-	-	-	-
Potato	-	-	-	-	-	-

Note: '—' indicates that the price elasticity has not been computed because the price coefficient was statistically non-significant

It is found that food grain, mainly aman rice production displays very low price elasticity. In case of aus and boro, etc., the price elasticities of acreage are relatively high. The long-run price elasticity of yield, however, is higher than the short-run elasticity implying that the longer the period of adjustment is likely to be the investment in High Yielding Variety (HYV) and technology to which boro responds substantially. In case of wheat price elasticity appears insignificant.

Rahman (1986) studies on supply responsive in Bangladesh agriculture, and he estimates the supply response of Bangladesh crops along with rice and wheat for the period from 1972 to 1982. His study analyses rice as total and variety-wise. He applies classic Cobweb and partial adjustment model in all cases. The basic difference from previous studies has been the testing of output response directly in all crop (output as dependent variable) rather than using area only as a proxy for supply response estimation. He uses separate regressions to estimate the supply responsiveness of individual crop variety. The supply functions yield good results in most cases and the estimated supply elasticities are comparable to those obtained for other developing countries. In case of rape and mustard, the acreage response function utilized deflated price by one year lagged wholesale price index and one year lagged yield as the explanatory variables. The price elasticities of cash crops, e.g., jute, tobacco, cotton and sugarcane are relatively higher as one would expect. The price elasticity of boro rice, which is produced not only for subsistence, is also high. The rapid expansion in production of wheat took place in response to demand for food grain under substantial government support. The influence of relative price on wheat supply might be, therefore, not statistically significant. Rahman uses deflated harvest prices instead of conventional retail or wholesale prices. But the study has a major drawback; it used very small sample (1973-82). Most of the regression fit are relatively good. Furthermore, the short-run and long-run elasticity revealed mixed results. Rahman uses the OLS technique for estimation.

Alam (1992) conduct a study on supply response of major crops and their sequences on crop production. This study analyses rice as total and variety wise. A notable departure from previous studies has been the testing of output response directly in all crop output as dependable variable rather than using area only as a proxy for supply response estimation. This study is elaborate one in comparison with other previous studies in the context of time period (1971-87). He applies improved methods like Non-Linear least Squares and Maximum Likelihood (ML). Production response in terms of area allocations of all rice varieties and jute are estimated within the Nerlovian dynamic model framework. He considers the relative product price changes and other influencing factors like rain-fall, yield trends, price and yield risk for estimating the supply responses of all rice varieties and jute. He observes that the jute yield increase is not influenced by the preceding season's prices but conditioned by the availability of improved seed varieties and extension services. Jute areas are highly responsive to sowing period rainfall and jute to aus price ratio. He also observes that rice areas are highly responsive to deflated product prices. Growth and fluctuation of area, yield, production and product prices of these crops are also analysed prior to econometric estimates of area responses.

Yunus (1993) carries out a study on price response to farmers area allocation and updated other previous work done by Rahman and Yunus (1993) and Rahman (1986) increasing the crop coverage to include pulses. His sample size is (1973-89) which is larger compared to earlier ones. He also uses yield rate as one of the regressors. Nonetheless, his regression produces very good fits. The estimation of short-run and long-run elasticities is in the expected range, except wheat elasticities, which are very high. He also measures the yield elasticity of respective crops.

Shahabuddin and Zohir (1995) make a study in view of projections and policy implications of medium and long term rice supply and demand for Bangladesh. He applies 'Macguirk' and "Mundlak' model of dynamic productions system to estimate supply elasticities of rice for the period 1984-91. Their estimated short-run elasticities are consistent with results of earlier studies.

Alam (2001) recently has done a work on supply response of farmers' behaviour in terms of area allocation to different crops. In fact, this is an extended work of Alam's previous study (1982), the study period covered 1975 to 1995. For estimating supply response elasticities, expanded and modified equation has been used based on Nerlovian dynamic price expectations and area adjustment models. Supply response equation in terms of area allocation has been specified incorporating relative product price, rainfall during the sowing period (for rain fed crops), yield trend (technological change), yield and prices fluctuations as explanatory variables.

In this study both Maximum Likelihood (ML) and Non-linear Least Square (NLS) estimators are used for estimation purposes. According to this study, ML estimator explicitly incorporates stationary restrictions and it has been intuitively expected to do better, provided that the model specification is correct. The OLS is also used for estimation purposes.

Dorosh, Shahabuddin and Rahman (2002), studies in the light of price responsiveness of food grain supply in Bangladesh and projections 2020. The time series covers the period from 1972-73 to 1999-00. This work provides estimates of price responsiveness of rice production; in particular, area planted to rice, and then simulates supply and demand balance for rice under alternative scenarios. This study is to estimate the response of planned production to various explanatory variables. Due to various environment and climate factors, actual output has not been used as proxy variables. The issue of proper proxy for the dependent variable is explained in Rahman and Yunnus (1993). In this study actual acreage of the crop concerned is therefore the dependent variable.

The study applies alternative regressions to derive statistically significant results for both the Nerlovian and simple Cobweb models with different price variables. The study uses OLS for estimation purposes. The summary of selected regression results is presented in Table 3.2,

Table 3.2: Summary of Yield Regressions

Variable	1999/2000 Log Aman yield Rate	1999/2000 Log Boro yield Rate	1999/2000 Log Aus yield Rate
Constant	0.456 (3.69)	0.5313 (6.45)	-0.0793 (-0.816)
Time Trend	0.0007 (0.14)	0.01935 (5.45)	0.009 (2.183)
R^2	0.0021	0.0021	0.346
Adjusted R^2	0.1088	-0.1088	0.27

Note: Figures in Parentheses show the value of t-statistics

Results show no significant technological influence on aus area. But weather plays an important role in supply determination as indicated by the significance of flood dummy variables.

Begum *et al.* (2002) studies recently entitled on supply response of wheat in Bangladesh for the period of 1972 to 1998. He applies partial adjustment model for estimation. This study provides an idea to all those concerned with supply response of wheat, if, and to what extent, a given price policy will be effective in manipulating the wheat supply in Bangladesh. The study also analyses other major factors responsible for influencing wheat supply in Bangladesh including their specific responses. The study included major factors affecting the acreage decision of wheat .Factors are broadly grouped into two categories: *prices and non-price* variables. Partial adjustment model has been used to estimate the supply response of wheat. Under the partial adjustment hypotheses, three different supply equations of wheat have been used to estimate the supply response of wheat. These equations cover ten variables that have been statistically significant. The study states that price response of wheat under the partial adjustment model is 0.67 in the short-run and 1.06 in the long-run. The adjustment coefficient is 0.63 for wheat during the study period.

Haque, Hossain and Rahman (2004) carry out a study on growth analysis and forecasting of rice production in Bangladesh. The study makes an extensive use of secondary time series data of rice production for four regions and also for Bangladesh as a whole for the period 1973-1974 to 2000-01. The study tries to find out appropriate models using seven contemporary model selection criteria that can best describe the growth pattern of rice production in Bangladesh. Here, an attempt is made to identify the best models for Bangladesh using seven contemporary model selection criteria such as R^2, adjusted R^2 Root Mean Square Error (RMSE), Akike Information Criterion (AIC), Schwartz Information Criterion (BIC), Mean Absolute Error (MAE) and Mean Absolute Percent Prediction Error (MAPE), (Gujarati, 2003). Attempts are also made to describe the growth scenario and to make forecasts of rice production in different regions and overall Bangladesh using the best fitted models.

All studies have been made on the basis of Nerlovian model frameworks, used acreage response with the price changes.

In context of estimation procedures, these previous studies use traditional tools and techniques, like simple linear equation and Ordinary Least Square (OLS). These studies use time series data irrespective of stationary and non-stationary situation. But in practice it is observed that time series data is not essentially stationary. So, previous studies do not give any attention to time series variables whether it is stationery or not. Such non-stationary data can produce *spurious regression*. It means that outcomes of the regression do not forecast significant relationships among the variable. The aim of this study is to increase our understanding of specification and estimation of agriculture supply response in Bangladesh as well as to provide instrument for agriculture planting decision and price policy by using co-integration and error correction mechanism with careful attention to time series data to avoid spurious regression of traditional econometric analysis. This is the strength of this study. In addition, to this the following problematic issues will be considered in the present study:

- Most of the previous studies do not cover sufficient number of observation for time series analysis.

- Product price selection is an important issue for proposed field. Because product prices highly fluctuate throughout the year. Now the question is which time period would be the best appropriate for policy purposes. The degree of responsiveness is also important for policy formulation. Most of previous studies use annual average prices except Alam's study. Farmer' response to harvest period prices is more logical in context of primary market in rural Bangladesh[4].

- None uses rainfall or weather variables in model specifications except two studies (Cummings, 1972 and Alam, 1992).

- If the disturbance term is well behaved, use of OLS with lagged dependent variable on the right hand side of the dynamic equations gives consistent and efficient estimates (Johnston, 1984:362). If the disturbance term in dynamic mode is auto correlated then the OLS estimator are not efficient. The proposed study will carefully consider the chance of auto correlation.

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[4] It is seen from Quesem's(1987) and Akther's(1989) study that around 40 percent annual paddy gross sales made by households during the harvest period.

Table 3.3: Some Supply Response Studies other than Bangladesh

Studies	Model	Country	Supply Response	
			Short run	Long run
Griliches(1959)[N]	Nerlovian	USA	0.28	1.20-1.32
Griliches (1960)[N]	Nerlovian	USA	0.10-0.20	0.15
Tweeten and Quanee(1968)[G]	Griliches	USA	0.25	1.79
Rayner(1970)[G]	Griliches	U K	0.34	0.42
Pandey et al (1982)[N, G]	Nerlovian, Griliches	Australia	0.30	0.6-1.00
Reca (1980)[N]	Nerlovian	Argentina	0.21-0.35	0.42-0.78
Bapna (1980)[N]	Nerlovian	India(Ajmer)	0.24	na
Krishna (1982)[N]	Nerlovian	India	0.20-0.30	na
Chhibber(1989)[N]	Nerlovian	India	0.20-0.30	0.40-0.50
Bond (1983)[N]	Nerlovian	Ghana	0.20	0.34
		Kenya	0.10	0.16
		Cote d'Ivorie	0.13	0.13
		Liberia	0.10	0.11
		Madagascar	0.10	0.14
		Senegal	0.54	0.54
		Tanzania	0.15	0.15
		Uganda	0.05	0.07
		SSA	0.18	0.21
* Mckay, Morrisey and Vaillant(1998)	Cointegration and ECM	Tanzania	.35	na
* Mustaq and Dawson(2002)	Cointegration and ECM	Pakistan	wheat 0.155 cotton –0.28	wheat 0.69 cotton 1.09
* Khalid Mustaq (2000).	Cointegration and impulse response	Pakistan	na	wheat=0.93 cotton=0.30 sugercan 5.01

Note: N stands for Nerlovian model and G stands for Griliches model.

Source: Various publications on supply responses at international level.

Aggregate supply response for different countries is presented in Table 3.3. These time series studies produce almost low estimates for the price elasticity of aggregate agricultural products supply. Table 3.3 depicts short-run estimates of elasticity range from 0.1 to 0.3. It indicates that the aggregate response to price changes is small in the short-run. However, long-run elasticities are higher and its range is from 0.5 to 1.7. Most of the studies have been used simple linear regression, ML and OLS to analyse results within Nerlovian or Griliches framework without any checking stationarity.

In Table 3.3, the last three studies (* mark) on supply response have been done following cointegration and Error Correction Model to avoid spurious results. These studies are playing significant roles to forecast accurately planting decision at national level. These studies are more specific and able to forecast more accurately than any other previous studies. The outcome of these studies has empirical value to formulate crop production policy and related issues at national level.

In Bangladesh supply response study at national level has not been done yet using econometric tools like cointegration and Error Correction Model. This study is following cointegration and ECM models. The out comes of this study is extremely valuable for making agricultural policy like agriculture price policy, crop production policy, food policy, and price support policy.

3.3 Conclusions

This chapter examine supply response literature at national and international level. Yet any vigorous studies on food grain production have not been done. Though Bangladesh agriculture is rice based. As a result, Bangladesh still suffers from food deficit and the country is struggling to reach food-self sufficiency. But it is prime need to forecast accurately at national level of planting decision towards supply-demand balance for food grain self-sufficiency and making a pragmatic crop production strategy. So, the present study will be the gateway of supply response on agricultural crops in Bangladesh. After the period of independence food deficit has became a regular problem in Bangladesh economy. The basic causes of food deficit are:

Firstly, Rapid growth of population, *secondly,* supply-demand imbalances due to slow growth rate of food grain production, *thirdly,* no realistic projection on supply-demand of food grain production in Bnagladesh.

To meet the above issues we need an integrated agriculture policy which covers price policy, food policy, and price support policy. To formulate these policies we need a scientific as well as intensive study on agriculture sector in Bangladesh. Finally, after going through the review of literature, its outcomes will lead to further study in this field.

Appendix 3.1: Summary and Information of the Previous Supply Response Studies in Bangladesh

Study Source	Crops	Period Studied	Models used	Dependent Variable	Independent Variables
Hussain (1964)	Jute	1948/49-1962/63	Simple linear three specifications	i) Acreage	
				ii) Jute acreage to jute+rice area	Relative jute price to aus rice price
				iii) Jute acreage to aus+jute area	
	Rice	1948/49-1962/63	Simple linear three specifications	i) Aus and aman acreage	
				ii) Aus and aman average relative to rice+jute	Price of rice (aus+aman) relative to jute price
				iii) Rice acreage relative to rice+jute for 9 districts	
Rabbani(1965)	jute	1948/49-1966/77	ii)Price expectations model	Acreage	Relative jute to rice prices, lagged area, dummy variables. trend
Cummings (1974b)	Rice	1949-1968	Price expectations model	Acreage	Price deflated by a cost of living index, lagged area, rainfall, trend
	Jute	1947-1968	Price expectations model	Acreage	
Ahmed (1984)	Rice	1960-1977	Price expectations model	Acreage	Price, weather index, trend
(1977)	Jute	1961-1974	Area adjustment model	Acreage	Relative jute to rice price, relative yields (jute/rice)
Rahman (1986)	Aman	1972/73-1981/82	Partial adjustment model	Acreage	Price of Aman deflated by wholesale price index, lagged acreage dummy variable
	Aus	1972/73-1981/82	Simple linear	Acreage	Price of Aus rice deflated by wholesale price index last year's yield
	Boro	1972/73-1981/82	Simple linear	Output	Price of Boro deflated by wholesale price index, dummy variable, last year's yield
	Jute	1972/73-1981/82	Simple linear	Output	Jute-aus price ratio, last year's yield, dummy variable
Alam (92)	Rice Wheat Jute	71-87	MLE Non-Linear least suares	Acreage	Harvest prices, weather (rain fall, expected yield risk)
Yunnus (93)	Rice Wheat	72-89	Simple Linear	Acreage	Price, technical change weather
Shahabuddin and Zohir (95)	Rice Wheat	84-91	Macguirk and Mundlak model	Acreage	Price

Note: This table has been formulated on the basis of Dorosh, Shahabuddin and Rahman's article published in BIDS, journal March - June, 2002, titled, price Responsiveness of Food grain supply in Bangladesh and projections, 2020,

Chapter 4
Theoretical Aspects of Supply Response

4.1 Introduction

The concept of supply response relates with a number of factors like price of product, input costs, technology, price of alternative products and unpredictable factors such as weather. There are two aspects of supply response

The *one* is technological aspect that exists between any particular combination of inputs and the resulting levels of outputs. This is represented by the production function. *Another* is the producer's behaviour in choice of inputs, given the level of market prices for commodities and factors that can be traded, and the availability of fixed factors whose quantity could not be altered in the period of analysis. It is experienced that most of the supply response studies have been analyzed on the basis of model formulation. In estimation procedure of supply response, studies frequently used theoretical model to quantitative measurements. It is also seen that most of the supply response studies rotated by price elasticity of supply response. Because, most of these studies have been considered prices as a decision making instrument for land distribution.

The major factors affecting the acreage decision of a particular crop are broadly grouped into two categories: *price* and *non-price* variables. The possible price variables affecting the area allocation are price of respective crops, price of competitive crops, input prices (fertilizers, labour etc). *Similarly*, some non-price variables that are likely to affect the acreage allocation are weather conditions, irrigation infrastructures, technology, risk variables and farmers' resource holding.

It is also experienced from the supply response literature that most of the studies focus on acreage under cultivation as a measure of supply rather than output or yield because of various seasonal and other factors that can influence yield year to year (Mushtaq, 2000:62). It is common instrument to measure quantity supplied is acreage under cultivation to a crop rather than its level of output: *"the actual area planted in particular crop is, to a much greater extent than output, under farmer control"* (Behramen, 1968:152).

4.2 Supply Response in Agriculture: Firm's Behaviour Perspective

Supply response is not a new issue in production economics. But it has great utility to explain supply side behaviour of agriculture agents. Most of the studies on supply response in peasant agriculture in developing countries relate to producer respond to change. Empirical research on supply response of agriculture explains (mainly) time series studies that examine output movements in relation to price movements within countries over time. Now we consider farmers' behaviour in context of supply side of agricultural output. If the objective of the farmer is to maximize profits then he will allocate resources among different crops according to the relative prices of these crops. In case of cash crops, farmers would be motivated by profit consideration. In context of Bangladesh, agricultural product (major crops) supply response to movement in expected price display curiously large variation crops, regions and time periods.

To understand fully the supply behaviour of the agricultural industry, one must understand the supply behaviour of firm or individuals in context of enterprise behaviour or subsistence level behaviour. Understanding of the supply concept in agriculture is furthered by considering the supply behaviour of three categories of farms: (1) Low-production family farms, (2) Commercial family farms, and (3) Larger-scale commercial farms. We will concentrate on the supply behaviour of small farms in context of developing countries like Bangladesh. With inadequate production resources in category (1) of the common family-type farm where the family provides management and most of the labour required in category (2), and of the large-scale operation largely dependent on hired labour and specialized management in category (3).

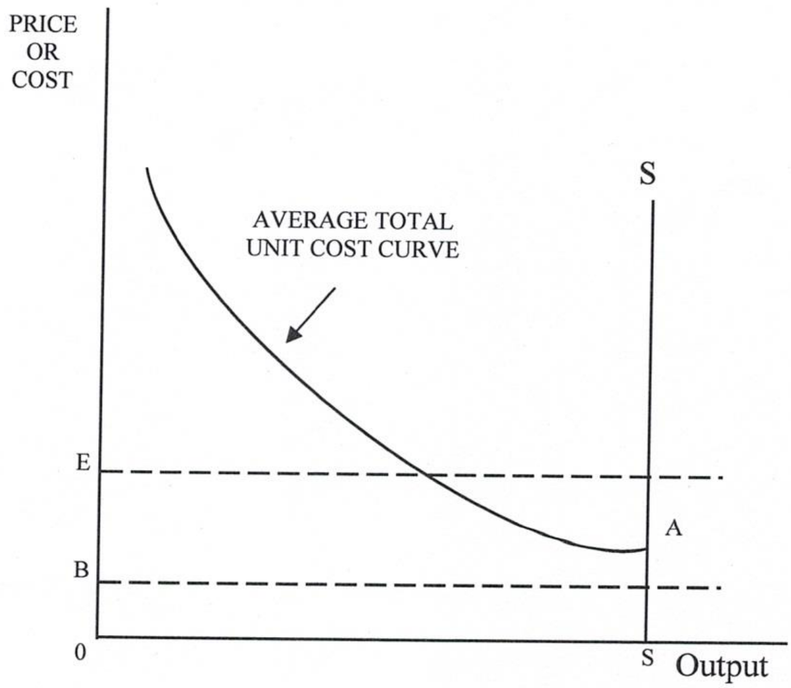
4.2.1 Supply Behaviour of Low-Production Family Farms

The principal productive resources-land and labour-are fixed in the typical low-production farm. Lacking access to sources of financing and having limited contacts with the commercial world, the typical farmer in this category treats land and labour as given, producing as much product as he is able with those given resources. His limited capital resources are typically of "sunk" type (that is, antiquated machinery and buildings with low salvage values). Thus, we conclude that the typical and principal resource inputs on these farms do not vary in use with the return to them; for practical purpose, the supply of various inputs is highly or perfectly inelastic.

Because family members on low production farms often seek and take off-farm employment, it should not be concluded that the supply of family labour is elastic. Off-farm employment does not vary with return to labour, which is shockingly low at all times on these farms; it varies with off-farm employment opportunities. When off-farm employment opportunities of a suitable nature are good, family labour on low-production farms leaves agriculture at a rapid rate. But with any given set of off-farm employment opportunities the family the family labour supply on low-production farms is highly inelastic.

A fixed cost or fixed input model best describes the supply behaviour of low-production farms. The costs of fixed resources run on whether they are used partially or fully. The optimum use of resources on a farm with fixed resources is, thus, a full use of resources. The farmer produces as much as he can with his often limited managerial ability and with his available resources, and there he stops. He does this because the more he produces the lower his unit costs become. Hence, he maximizes his return or minimizes his losses by producing to the limit of his capacity in this case.

Figure 4.1 The supply Relation for a Typical Low Production Family Farm



Source: Wilcox and Cocltrane, 1960:73

This type of supply behaviour is illustrated in Figure 4-1. Unit costs fall, where resources are fixed in the farm, as total output increases. Thus, the fixed resources are utilized as fully as possible and output is pushed to the maximum. Total output is pushed to point A, and there it holds constant, regardless of price. More cannot be produced because of resource limitations, and less will not be produced regardless of the level of price, or prices, at point A, profits are maximized with a price of OE, or losses are minimized with a price of OB. Thus, the supply curve of the low production farm may be conceptualized as line SS in Figure 4-1.

Since, as is implied, there is no change in management ability within the production period and the resource inputs of land and capital are severely limited as well as fixed on these low-production farms, output from such farms is small as well as inelastic.

4.2.2 Supply Behaviour of Commercial Family Farms

We find two classes of inputs on commercial family farms, (1) those that are typically varied, and (2) those that are not. Let us consider the second category first. The most important input that is held fixed for the farm as a whole is labour. Typically, the family supplies all or most of labour on family farms, as operations on such farms are adjusted to size, composition and abilities of family labour supply. At very high product prices, hence high labour returns, the family labour supply may be augmented by hired labour, and the converse at very low product prices, but over the range of accustomed product prices and labour returns, supply of labour on commercial family farms is varied relatively little in response to returns to labour. The family is the labour supplier. This is the unique and distinguishing feature of family farm.

Land inputs on the representative family farm are largely fixed. The land area of the representative farm is not easily expanded or contracted. One farm can acquire land at the expense of another, but not all arms (that is, the representative farm) can expand. Many capital inputs–for example, buildings, irrigation structures, orchards, and specialized harvesting equipment-are "sunk" inputs. The salvage value of these capital items is so low once they are committed to production that no thought is given to varying such inputs. Or stated differently, the salvage value of these capital items is so far below acquisition costs that marginal value product of such items can vary over a wide range with fluctuations in farm price level without there being any incentive to acquire more, or to dispose, of those already acquired. Finally, feed supplies on representative farms tend to be fixed in the short-run (although inter-temporal substitution under government storage programs modifies the fixed input argument somewhat with regard to feeds).

But some inputs can be and are varied on commercial family farms. Typically they are inputs acquired from non-firm sector. Fertilizer is the classic example. Other such inputs might include veterinary services, pesticides, plant disease control, and repair of machinery and equipment. The use of these resource inputs does very with level of product prices, hence with return to them.

4.2.3 Supply Behaviour of Large-scale Commercial Farms

This class of farms differs from commercial family farms in one important respect; labour is a highly variable input factor on large-scale farms. It is hired and fired as profit maximization dictates. When low or falling product prices make the intensive use of labour on a large–scale farm unprofitable, same labour is sent packing down the road. When high or rising product prices render the intensive use of labour profitable, additional labour is recruited in urban areas or outside the country (in Mexico, for example).

Thus, we would expect the supply relation for the large-scale farm to be mare elastic than that for the family firm in comparable situations. However, some specific inputs tend to remain fixed even on large-scale farms. The land area of the representative large–scale farm is not readily increased. And numerous capital inputs become sunken inputs and no variable on large-scale farms as well as on family farms (for example, building, orchards). To some degree, then, the cost structure of large-scale farms must float with price level, and this action tends to reduce the incentive to expand, or contract, total output of farm.

4.3 The Classical Production Theory

A production function is a quantitative or mathematical description of the various technical production possibilities faced by a firm. The production function gives the maximum output(s) in physical terms for each level of the inputs in physical terms, which is mathematically expressed as

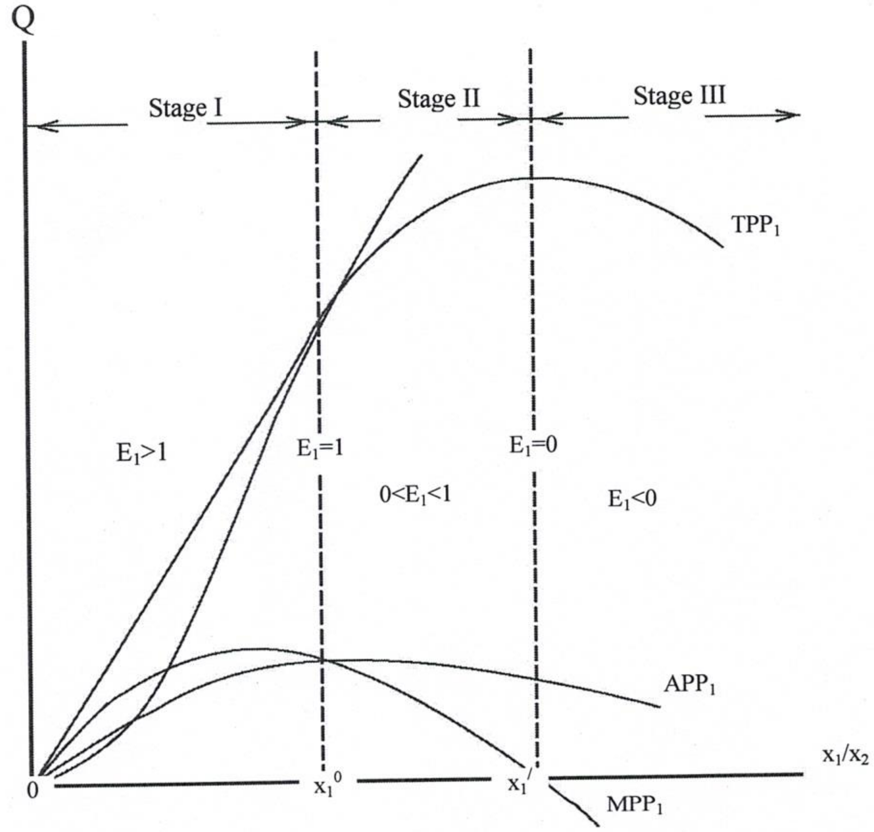
$$Q = f(x_1, x_2)$$

Where Q denotes output, x_1 is variable factor of production (input) and x_2 is fixed factor and f denotes function. To simplify notation, output for a fixed production period and a given plant with only a single variable factor is represented by $Q = f(x)$. The fixed factor x_2 is not written down for national convenience. Output Q is referred to as Total Physical Product *(TPP)*

Another important physical concept is Average Physical Product *(APP),* defined as $\text{APP} \equiv \frac{Q}{x} \equiv \frac{f(x)}{x}$, A third and most important concept is Marginal Physical Productivity *(MPP)* defined as $MPP \equiv \frac{d(TPP)}{dx} \equiv \frac{dQ}{dx} = \frac{df(x)}{dx} = f'(x)$

Figure 4.1 expresses fundamental relationship among Total Physical Product *(TPP)*, Average Physical Product *(APP)* and Marginal Physical Product *(MPP)* with elasticity ranges.

Figure 4.2: Classical Three-Stage Production Function and Marginal and Average Curves—Single Factor Variation



Elasticity of production expresses the physical relationship between output and input or factor. Factor elasticity that is partial elasticity of production and total elasticity of production found are in production economics literature. Factor elasticity refers to changes if one factor is varied and all others are held constant, whereas total elasticity deals with the case where all factors are varied in fixed proportions.

Factor elasticity, E, for our single-variable input production function, $f(x)$ is defined

as $E \equiv \frac{dQ/Q}{dx/x} = \frac{dQ}{dx}\frac{x}{Q} = MPP\frac{1}{APP} = \frac{MPP}{APP}$

E is a measure of the percentage change in output in response to an infinitesimal percentage change in a factor given that all other factors are held fixed. If E is greater than one, an increase in the input level will result in a more than proportionate increase in output; for $E<1$, the proportionate increase in output is less than that of input; and for $E=1$ the proportionate increases are equal. According to Figure 4.1, in stage two where elasticity range is $0<E<1$ and *MPP<APP, MPP* is decreasing but positive. This stage treated as economic zone and this is the appropriate stage for producer for operates. In this stage Diminishing Marginal Returns remain effective on the production function.

4.4 Law of Supply Response

Before moving on supply response, it is needed to discuss about some basic aspects of supply function. The supply function is the mathematical relationships between real prices of a commodity and quantities supplied by producers at each price for a given market per unit of time, other things being equal. Many variables such as technology, weather, and investment in infrastructure, and prices of related commodities and of inputs shift the supply curve.

Supply curves and functions are useful to answer many questions often confronted in agricultural policy analysis.

- If supply price is raised or lowered, how will the quantity supplied of commodities respond?
- Is the response different for a short-run of 1-2 years versus a long-run of 10 years or more?
- Is it more effective and efficient to increase output by raising commodity prices to move along the supply curve or to shift the supply curve forward by investment in agricultural education, research, and extension?
- If price is raised for one commodity, how is the production of other commodities affected?
- Is a subsidy to fertilizer and irrigation more effective than a commodity price increase in generating output?

Supply function expresses supply quantity as a function of several variables:

$$Q_{it} = f\left[\frac{P_i}{w}, \frac{P_j}{w}, I, T, G, \varepsilon\right] \qquad (4.1)$$

Where Q_i is production of commodity supply i; P_i is own-price of i; P_j is the price of competing commodities (represented by an index of prices received by producers or by separate price variables for each commodity); w is prices paid for inputs (represented by an index of prices paid for all inputs or by separate prices of fertilizer, machinery, labour, pesticides and other inputs); I is fixed capital inputs or infrastructure, such as, public irrigation capacity; T is technology such as high-yielding varieties or productivity which is often represented by a time trend; and ε is random error. Other variables, such as the *variation* in past prices may also influence the supply quantity.

Elasticities are frequently used for convenience to express the supply response to price.The elasticity shows the percentage change in one variable associated with the percentage change in another variable and hence is independent of the units of measurement. Elasticity is frequently measured at the mean of price and quantity.

For example, the own *price elasticity of supply* response is;

$$E_{ii}=\frac{\Delta Q_i}{Q_i}/\frac{\Delta P_i}{P_i}=\frac{dQ_i}{dP_i}\frac{P_i}{Q_i}=\frac{d\ln Q_i}{d\ln P_i},$$

Where Δ, denotes change and d refers to a very small change.

There are three types of own price elasticities as:

$E_{ii} > 1$ means supply is elastic,

$E_{ii} < 1$ means supply is inelastic, and

$E_{ii} = 1$ means unitary elasticity.

The magnitude of the elasticity depends on how much time period is allowed for adjustment. It is experienced from practical observation in the long-run farmers are able to make full adjustments to changes in prices. In most cases, the long-run elasticity is higher than the short-run elasticity.

The cross price elasticity for related products is represented as;

$$Eij=\frac{\Delta Q_i}{Q_i}/\frac{\Delta P_j}{P_j}=\frac{dQ_i}{dp_j}\frac{P_i}{Q_i}=\frac{d\ln Q_i}{d\ln P_j},$$

Cross price elasticity measures the proportionate change in quantity of one product due to proportionate change in price of other related products. Cross price elasticity is used to measure substitute, complementary and joint products. Now let us consider an example, in competing crop say if P_j increases it leads to decrease in output supply Q_i provided other thing remaining unchanged. In that case farmers would like to produce more output of Q_i due to profit.

Nature of cross price elasticities as;

$Eij > 0$ implies complementary products/joint products

$Eij < 0$ means substitute products/ competing products

$Eij = 0$ indicates not related products.

And the elasticity of response to input prices is

$$Eiw = \frac{\Delta Q_i}{Q_i} / \frac{\Delta w}{w} = \frac{dQ_i}{dw}\frac{w}{Q_i} = \frac{d\ln Q_i}{d\ln w}$$

Input price elasticity measures the proportionate change in quantity of a product due to change in input prices. Usually input price elasticity is negative; because increase in input price leads to increase in producers' marginal cost and finally it negatively affect the output supply and *vice-versa.*

In studying supply response, it is important to distinguish between specific crops and broad agricultural aggregates, and between short-run and long-run responses. Price elasticity, which depends on impact of the price on the use of variable factors only, is thus a short-run concept. If most factors used in agriculture are fixed in the short-run, as it is often claimed, then supply elasticity is close to zero (Elisabeth and Alain, 1998:72).Fixed factors, such as, irrigation from tube-well, herds of livestock or equipment that can be introduced through private investment involving with a certain time lag. Public price support policy, agriculture related infrastructure etc are the long-run aspects in production economics. Considering these long-run effects (that may be private and public) of price incentives leads to farmers long-run production response of agriculture. It is distinctly greater than what it is captured by only short-run variable adjustment. Now we consider short-run and long-run elasticities with considering endogenous and exogenous factors. Following this purposes we can write a production function of a firm as:

$$h(Q, x_1, x_2) = 0$$

Where Q the vector of output quantities is, x_1 is the vector of variable input quantities. Variable inputs are usually labour, fertilizer, water, pesticides, seeds, and hours of rented tractor use. Fixed factors x_2 are either private factors that cannot be acquired in the time span analyzed (land equipment), or public factors (infrastructure and extension services), or exogenous features (such as distance to market).

Now decompose the vector Z in three categories: k for private fixed factors, k^* for public goods, and t for truly exogenous factors. The long-run response is defined by allowing k and k^* to adjust to price, to exogenous factor t, and to variable representing government policy g. The derived system of supply and demand becomes:

$$Q = Q(P, k, k^* t)$$

$$k = k(P, k^*, t)$$

$$k = k\{P(i)\}$$

$$E_{ij}{}^{L} = \frac{\partial \ln Q_i}{\partial \ln P_j} + \sum_i \frac{\partial \ln Q_i}{\partial \ln k_1}\left(\frac{\partial \ln k_1}{\partial \ln P_j} + \sum_m \frac{\partial \ln k_1}{\partial \ln k_m^*}\frac{\partial \ln k_m^*}{\partial \ln P_j}\right) + \sum_m \frac{\partial \ln Q_i}{\partial \ln k_m^*}\frac{\partial \ln k_m^*}{\partial \ln P_j}$$

$$= E_{ij}{}^{s} + \sum_i E(q_i / k_1)\, E(k_1 / P_j) + \sum_m E(Q_1 / k_m^*) E(k_m^* / P_j) + \sum_{11.m} E(Q_i / k_t) E(k_t / k_m^*) E(k_m^* / p_j)$$

Similarly, long-run the supply response with respect to the t variable is:

$$E^L(Q_i / t_n) = E_{in}^s + \sum_t E(Q_i / k_t) E(k_1 / t_n) + \sum_m E(Q_i / k_m^*) E(k_m^* / t_n) \qquad (4.2)$$

Using equation (4.2), the long-run direct price elasticities can be calculated when only the private variables are allowed to respond to price changes and when both private and public variables changed. In most cases, the long-run elasticity is, as expected, substantially higher than the short-run elasticity.

Supply response may differ for the short-run versus long-run, for rising prices and falling prices, and for a crop that occupies a large share of land share or small share. The production process in agriculture is relatively long. Consequently, a decline in prices may not be followed at once by a reduction in output. Farmers will find it advantageous to complete the production process as long as price equals or exceeds the marginal cost of completing production process as of any moment of time

(Johnson, 1960). Thus adjustment process in agriculture cropping is long and also delayed. So time lag is a crucial element in supply response phenomena and it should be introduced in empirical studies. The supply response model that has already been discussed is static and insufficient. So it is needed to consider dynamic specification of supply response model because farmer does not react to price instantaneously to adjust their production, they also consider the past prices.

The responsiveness of output supply depends on applications of fertilizers, insecticides, High Yielding Variety (HYV) and these can produce some increases in total output, but if output of a sector is considered as fundamentally determined by factor inputs and technologies. In this connection agriculture output can be increased output in response to an improvement in its terms of trade chiefly by attracting factors from other sectors and / or by improving cultivation techniques. In the short-run both techniques and factors supplies will be relatively fixed. It is only after a considerable period-perhaps several years, which much can be done about these things. Finally, it is said that supply response of output in agriculture sector is not an instantaneous phenomenon, rather it is a phenomenon of past and future aspects of various factors specially farmer's pervious experience of market prices. So supply response is dynamic in nature.

4.5 Factors Determining Supply Elasticity of Agricultural Products

Elasticity of supply of agricultural products or commodity depends on various factors; some of them are stated below:

a. *Nature of commodity*: elasticity depends on nature of commodity. The commodity or product (especially agricultural products) whose production cannot be increased in short-run its elasticity is inelastic. If any changes in prices; agricultural products don't response in supply in short-run. This is distinguishing characteristics of agricultural products.

b. *Supply of input:* If components or inputs of a commodity are easily available, the supply of such things is comparatively elastic. Cost of production, transportations, storage etc. are important criteria of supply.

c. *Cost of production*: For any kind of production process, cost of products and marketing facilities are important conditions for supply. If these conditions become easy to fulfil, the supply of such commodity may be elastic because, the cost of production increases with prices. But supply of a commodity produced under diminishing return is elastic. So supply of farm products is inelastic in this sense.

d. *Durability*: Supply of perishable commodities, like milk, fish vegetables fruits etc, is inelastic. Due to seasonability and perishability these agricultural products must be sold at any price to overcome loss of any kind.

e. *Technical aspects of production process*: The supply of products whose process of production is simple is elastic. But the product, whose technological process is rather complicated, is inelastic. For example; supply of frozen food, drinks etc, and is inelastic.

f. *Expansion of market*: If market of a commodity is expanded, supply will be elastic. On the other hand, if market is contracted, supply of commodity will be inelastic. In general, supply of agricultural commodities is inelastic by nature due to high cost of inputs, inadequate transport and storage facilities.

g. *Time*: Time is another variable with a crucial influence on the size of supply elasticitites. People need time to decide on their response to new opportunities and for these decisions to take effect. Sometimes long gestation lags occur between a decision and resulting change in production, particularly when major new investments are necessary.

In the short-run, the supply elasticity of agricultural products tends to be very inelastic for three reasons. *Firstly,* a high proportion of the costs of production are fixed in the short term so that the scope for curtailing costs by reducing production is severely restricted. *Secondly,* because of their immobility, the opportunity costs of agricultural land, labour and machinery are frequently. *Thirdly,* the short-term inflexibility of agricultural production is partially explained by biological factors.

In summary, the main biological factors affecting the elasticity of supply of agricultural products are the length of production cycle, the constraints imposed by diminishing returns on the economic utilization of feeding stuffs, fertilizers and other inputs, the seasonability of supply and perishability of products which, because of uneconomic storage costs, limits the scope for holding stocks.

4.6 Role of Non-price Variables

This section discusses the role of non-price variable on supply response. The economic activity, of an agro-based producer is dominated by the non-price variables, like physical, institutional and technological and also demographic.

Firstly, the development of agricultural production is dependent on three basic physical factors-soil, land and water. Bangladesh, like many other countries, has several soil types, which are deficient in micronutrients, organic matter content or have other physical shortcomings. Some of these constraints can be removed; especially be nutrient deficiency while other problems will not be so easily remedied.

Land is a lasting key factor for production, which has vast multidimensional aspects in production economics. This issue will not be considered for discussions in this study.

Water management is perhaps the key factor in agricultural production. Rainwater, irrigation and residual soil moisture are essential for growing crops. Three factors related to soil are flat topography of land, seasonal influx of water through the river networks and the monsoon rains these represent physical condition that has significant effect on agriculture production.

Secondly, let us consider the institutional aspects of the supply side economy. The institutions are here defined as the behavioural rules and organizational structure that may be endogenous or exogenous factors[5] related with entire production and distribution processing. In short, the supply curve for institutional change shifts to the right as a result of advances in knowledge in social science and related professions (Boyce, 1987:26).

Thirdly, technology is one of the most important determinants of the shape of agriculture production. Economists often define technology as 'the sum of knowledge of the means and methods of producing goods and services' (Bannock *et al.*, 1978:433). It is needed to differentiate between techniques and technology. A technique is a specific method of production. Technology refers to the spectrum of

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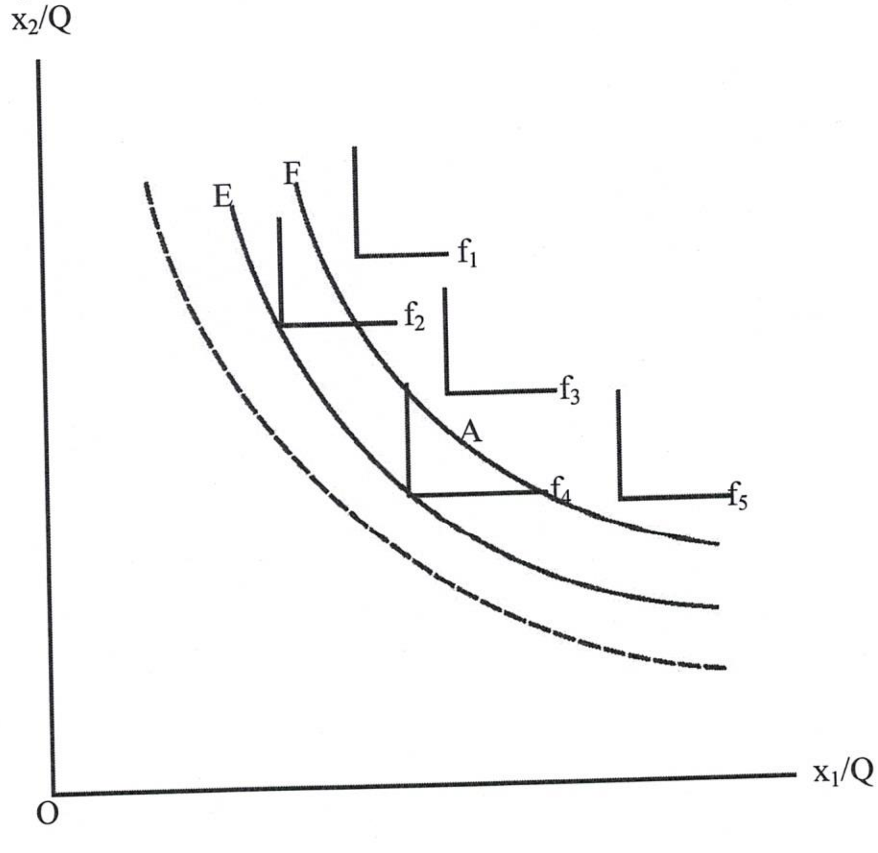
[5] Institution has been treated in some cases as endogenous and some cases as exogenous factor in production cases. It dependents on how institution factor introduced in the model. See for detail literature Lee, 1981: 55-59.

techniques in the economy. Technology, is the sum of knowledge, could be defined either as the technically efficient set of available techniques, which produce maximum output for each input combination, or as the average spectrum of techniques in use, 'the centre of gravity of each ray of factor ratio' (Lee, 1981:57).

The term 'technological' frontier will be used to refer to the spectrum of the most efficient techniques in use. These concepts portrayed graphically, for the simple case of factors x_1 and x_2 in Figure 4.3.

Figure 4.3: Technique, Technology and Technological Frontier



Source: Lee (1981:57)

The axes represent the quantities of these factors at a given level of output or, if constant returns to scale are assumed, the ratio of these factors to output. The *L*-shaped curves, f_i, depict techniques currently in use. The curve *F* represents technology, and the envelope curve E represents the technological frontier. The current state of technology in use could also be represented by the average technique, the average input-output combination for all producers, represented as point A. 'Technological change' refers to shift in curve F, and comes about through technical changes of individual producers.

Shifts in technique occur for two basic reasons: improvement in productive efficiency, i.e., a movement towards the technological frontier. Which, it may shift inward or outward as new techniques are discovered; and factor substitution, prompted by changes in relative prices. Both can occur simultaneously.

Technological change can influence the production function in various ways. More specifically, techniques vary in a number of dimensions to economists, including scale, reliability, ratio of fixed to operating costs, use of imported components, seasonability of labour demand, level of group action required, and factor-output ratios such as productivity (output per unit labour) and crop yields (output per unit land).But it is the ratio of capital to labour that has evoked the strongest interest. The concept of the 'direction of technological change refers to changes through in this dimension. A technological change is labour saving if it increases the capital-labour ratio, capital-saving if it decreases it, and neutral if it leaves it unchanged.

4.7 Risk and Uncertainty in Supply Response

Risk and uncertainty has always been a part of agriculture in both developed and developing countries. Output from farmers depends on weather, biological and other processes over which producers have little, and limited control. Moreover today, the competitive structure of domestic and international product markets expose is producers to unanticipated fluctuations in prices. In fact, instability, variability, and risk have all played an important role in motivating and justifying policy intervention in the agriculture sector.

Risk: The risk in agriculture are those events which are natural and independent or of random occurrence. The events are broadly grouped as meteorological and biological.

Meteorological: Windstorms, drought (famine), floods, tornado, cyclones etc.

Biological: Occurrence of various pests and diseases.

Pure risks involve complete knowledge of future events. Since knowledge of the future is complete. The losses and gains, which grow out of risk, can be predicted with certainty and can be incorporated into the firm's cost schedule.

Uncertainty: Uncertainty is a subjective prediction in contrast to pure risk, a probability of outcome cannot be estimated in an empirical or quantitative sense for uncertainty is always present when knowledge of the future is less than perfect.

Risk can be incorporated into farms (farmers) cost structure and is therefore insurable, which uncertainty are not insurable and cannot be reduced to cost. Basic types of uncertainty in agriculture:

i) Uncertainty in Production
ii) Uncertainty in Price

Examples of uncertainty in agriculture

i) Crop yield due to a variety of factors

ii) Number of days is available for field work

iii) Output prices

iv) Input prices

v) Accidents

In an economy where agriculture provides an important fraction of national income, here income stability in agriculture contributed significantly to income stability in the total economy. Instability of income occurred due to risk and uncertainty. Agriculture is characterized by the vagaries of nature such as scarcity conditions, excessive rains, cyclones, flood etc. These are causes of instability in output of agriculture sector. This will have the effect of reducing farmers' income and finally reducing farmer's consumption expenditures for purchased inputs and capital equipment (Dale, 1969:159).

It is found from the study of risk and uncertainty in agriculture by Baron (1970) and Sandmon (1971) that risk averse farms produce smaller output under price certainty and that the higher the overall level of risk, if other things remain constant, the lower the output.

Farmers do not produce farm products in the aggregate. They produce one or more products on an individual farm located in a specific place. In case of individual farmer's prices, are determined by shifts in demand and output of the commodity he produces. Price uncertainty of his commodities affects farmer's responsiveness to planned output/production. Farmers face as many sources of uncertainty when they plan their output and combinations of resources to produce most profitable output. In this respect, Price (1995) stated that uncertainty affects the farm's investment decisions negatively.

Due to imperfect knowledge about future the farmers cannot "hit the nil on the head" in predicting future yields, prices and production outcomes, he is faced with risk and uncertainty. *Six* important kinds of uncertainty give rise to imperfect knowledge and hence possible mistaken plans for the future. *One* is price fluctuation. Price changes more than anything else provides major uncertainty, although all types of uncertainty are extremely important in planning. Uncertainty in product prices creates an additional cost of production, which shifts the output supply curve to the left, resulting in less output. A *second* type is the yield or production uncertainty is a vital element in case of taking decision of which combination of crops should be grown and which of input combination should be applied. According to Newbery and Stigliz (1981), Dillon and Anderson (1990), Hardaker *et al.* (1997) price and production related risk and uncertainty influences the farmers in decision-making on input and output combination. A *third* type of uncertainty is that modernizing new techniques or methods of production. While this type of uncertainty for new methods are related to t yield[6], uncertainty where production may vary from year to year due to weather. A *fourth* important uncertainty involves government policy and decision of legislators. Farmers' decisions on support prices, storage programs, acreage allotments and production control, crop insurance and international trade policies affect prices received for farm products and output decisions. A *fifth* uncertainty involves actions of related economic agents with whom he do business. Landlord, neighbouring farmers, sharecropping, hired labours and financial institutions are related elements in this respect. A *six* risk surrounding any individual or family, whether engaged in

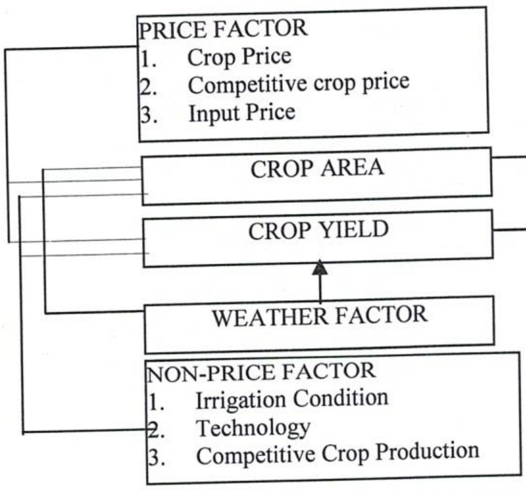
[6] New techniques and method is measured by yield rate of crop.

business for themselves or otherwise occupied, is the uncertainty of sickness, injury, or death.

Figure 4.4: (schematic model) expresses how crop supply is influenced by price (own price, input prices and price of competitive crops) and non-price variables (irrigation, technology and competitive crop production).Finally allocation of crop area and crop yield are the leading factors for crop supply in agriculture sector.

Schematic Model of Crop Supply has been drawn considering with price and non-price factors as follows:

Figure 4.4: Schematic Model of Crop Supply



4.8 Model Specification

Frequently the analyst desires more information than just the supply response to price. Suppose it is useful to know the contributions of specific resources and of yield and area components to supply response. Analysts may also find it useful to disaggregate supply response into area and yield components. It can be shown that the total output supply elasticity can be expressed as:

$E_{ii} = E_{yi} + E_{ai}\,(1+E_{ya})$

Where E_{yi} is the elasticity of yield with respect to product price P_i , E_{ai} is the elasticity of crop area with respect to P_i and E_{ya} is the elasticity of yield with respect to area. If crop area is expanded on marginal lands, E_{ya} is negative; if area is expanded on superior lands (say recently irrigated), E_{ya} is positive. If yield and area are independent, then total supply elasticity of output is a sum of yield and area elasticities.

Following economic theory of supply response and previous empirical studies on supply response, model specification for a particular crop can be formulated in terms of area, yield or output. Previous studies in Bangladesh in this connection have followed acreage as a measuring tool of supply response rather than output or yield (See chapter 4). Subsequently, these studies have produced arguments in favour of their selection of acreage as a measure of supply response. Most of these studies argued that various uncertain seasonal and other factors that can influence *yield and output* from year to year. So, related supply response studies used *acreage*-as a proxy of supply response. Planted area is frequent indicator of intended supply than output because the area (acreage) is relatively under control of farmer to a greater extent, whereas output is controlled by some exogenous factors such as weather, market forces, insects, pests and disease. In addition, it is common practice to measure the theoretical concept of 'quantity supplied' by the acreage planted of a particular crop rather than by its level of production (Mushtaq, 2000:57). If yield and output are used as dependent variable then it may produce misleading outcomes. Generally yields are price responsive but high variance of yield may facade the actual response. Besides, if output is used as the dependent variable, the true responsiveness of farmers may be flooded by the additional variability of yield.

From earlier discussions, variables that already identified on the basis of empirical literatures and studies to specify rice and wheat acreage model as following;

$$A_j = f(P_j, Q_j, P_c I, Y)$$

Where A_j, is the acreage under cultivation of crop j, P_j is its own price, P_c is the competing crop price, Q is output of respective crop, I is irrigated area under crop j and Y is yield. Supply response elasticities can be estimated empirically by multiple regression statistical analysis using data over time on the variables that already mentioned in equation 4.1.

4.9 Econometric Models of Supply Response

A large body of economic theory has emerged to explain supply response of agricultural product. These theories have been considered in context of methodological aspects of supply response and various quantitative approaches to supply response. In this section the applicability of these theories has been considered in context of supply response on the basis of theoretical arguments. The theoretical arguments will be made on the basis of following theories:

4.9.1 Nerlovian Supply Response Model

Marc Nerlove's supply response model has been treated as a fundamental model of crop studies. Nerlove's adaptive and partial adjustment models of supply response have been intensively used and modified by many researchers in crop studies at different aspects.

on the basis of Nerlovian supply response model can be formulated in terms of yield, area, or output response of individual crops. For instance, the desired area to be allocated to a crop in period *t* is a function expected relative prices and a number of factors:

$$A_t^d = \alpha_1 + \alpha_2 p_t^e + \alpha_3 z_t + u_t \tag{4.3}$$

In this equation A_t^d is the desired cultivated area in period *t*; p_t^e is the expected price (or more generally, a vector of relative prices including prices of the crop itself, prices of competing crops, and factor prices, with one of these price chosen as numeraire); z_t is a set of other exogenous shifters, principally private and public fixed factors and truly exogenous variables such as weather ; u_t accounts for unobserved random factors affecting the area under cultivation and has an expected value of zero; and α_i's are parameters (or elastic ties if variables are expressed logarithmically) with α_2 the long-run coefficient (elasticity) of supply response .

As full adjustment to the desired allocation of land may not be possible in the short-run, the actual adjustment in area will only be a fraction δ of the desired adjustment:

$$A_t - A_{t-1} = \delta\left(A_t^d - A_{t-1}\right) + u_t, \quad 0 \le \delta \le 1 \tag{4.4}$$

Where, A_t is the actual area planted, δ the partial-adjusted coefficient, and u_t is a random term with zero expected value. The central issue is that what the basis of forming expected prices is and how past prices can represent expected prices. Farmers must base their decisions on some reasonable assessment of the supply demand conditions for the commodities they produce. According to Nerlove farmers react, not to last year's price, but rather to the price they expect, and this expected price depends only to a limited extent on what last year's price was.

The price of the decision makers' expectations to prevail at harvest time cannot be observed. Therefore, one has to specify a model that explains how the agent forms expectations based on actual and past prices and other observable variables. For example, in a formulation that represents a learning process, farmers adjust their expectations as a fraction γ of the magnitude of the mistake they made in the previous period that is the difference between actual price and expected price in

t-1 as follows:

$$p_t^e - p_{t-1}^e = \gamma\left(p_{t-1} - p_{t-1}^e\right) + u_t, \; 0 \le \gamma \le 1 \text{ or}$$

$$p_t^e = \gamma p_{t-1} + (1-\gamma)p_{t-1}^e + u_t \qquad (4.5)$$

Where p_{t-1} is the price that prevails when decision-making for production in period t is occurred. Here γ is the adaptive expectations coefficient, and u_t is a random term with zero expected value. An alternative interpretation of this learning process is that the expected price is a weighted sum of all past prices with a geometrically declining set of weights:

$$p_t^e = \gamma \sum_{i=1}^{\infty} (1-\gamma)^{i-1} p_{t-i},$$

Where, the right-hand side,the geometric series is the solution to equation (4.5) which gives the certainty equivalent to p_t^e.

Since p_t^e and A_t^d are not observable, we eliminate them from equation (4.3), (4.4) and (4.5) substitution from equation (4.3) and (4.5) into equation (4.4) and rearrangement gives the reduced form:

$$A_t = \pi_1 + \pi_2 p_{t-1} + \pi_3 A_{t-1} + \pi_4 A_{t-2} + \pi_5 z_t + \pi_6 z_{t-1} + e_t \qquad (4.6)$$

Where: $\pi_1 = \alpha_1 \delta \gamma$

$\pi_2 = \alpha_2 \delta \gamma$, the short-run coefficient (elasticity) of supply response

$\pi_3 = (1-\delta)+(1-\gamma)$

$\pi_4 = -(1-\delta)(1-\gamma)$

$\pi_5 = \alpha_3 \delta$

$\pi_6 = -\alpha_3 \delta (1-\gamma)$

$e_t = v_t - (1-\gamma) v_{t-1} + \delta u_t - \delta (1-\gamma) u_{t-1} + \alpha_2 \delta w_t$

Equation (4.6) is the estimable form of the supply response model defined by equations (4.3), (4.4) and (4.5). This reduced form is over identified, since there are six reduced form coefficients π but only five structural parameters *($\alpha_1, \alpha_2, \alpha_3, \gamma$, and δ)*. The presence of the lagged values of the dependent variable on the right hand side makes the estimated parameters not only biased but also inconsistent if the error term is serially correlated.[7] In this context Sadoulet and de Janvry (1995) suggest that to

[7] To over come this problem different methods for estimation have been introduced in econometric literature, e.g.,(Maddala, 1989; Koyck, 1954; Nerlove, 1958c; Kmenta, 1986; Green, 1993).

obtain a unique solution for the latter, a non- linear constraint must be imposed on the parameters of the reduced form:

$$\pi_6^2 - \pi_4\pi_5^2 + \pi_3\pi_5\pi_6 = 0$$

The model should be estimated using non-linear Maximum-Likelihood techniques, and correlation needs to be made for serial correlation in the error terms. The structural coefficients are solved with the following equations:

$$\delta^2 + (\pi_3 - 2)\delta + 1 - \pi_3 - \pi_4 = 0$$

$$\gamma = 1 + \pi_4 /(1 - \delta)$$

$$\alpha_1 = \pi_1 / \delta\gamma$$

$\alpha_2 = \pi_2 / \delta\gamma$, the long-run coefficient (elasticity) of supply response,

$$\alpha_5 = \pi_5 / \delta$$

The short-run price response is estimated by π_2 and the long-run price response is calculated as α_2, where $\alpha_2 = \pi_2/\delta\gamma \geq \pi_2$ since both δ and $\gamma \leq 1$. As expected, the long-run supply response exceeds the short-run supply response.

The drawback of Nerlove's model has been highlighted mainly on its theoretical background and on its statistical estimation procedures when the Ordinary Least Square (OLS) method is applied (Johansen, 1960; Griliches, 1967; Doran and Griffiths, 1978; and Tweeten, 1985).

Nerlove's explanation about prices is in terms of current market realizations with normal or expected prices are specified in terms of past market prices. There has been controversy on which price series are appropriate for a particular crop. So it is difficult to form a price series at any particular period of time.

Second drawback of Nerlove models is that farmers do not necessarily change their expectations of prices on the basis of observed prices because they can consider this change as period phenomena. Therefore, formation of price expectations may overestimate the real expected price and as a result underestimate the true aggregate supply elasticity

Thirdly, it is assumed that price expectation coefficient is constant over the time. In fact, there are some technical and economic factors which can affect price expectations coefficient; these are not considered in the model.

Fourthly, Nerlove's model assumes that output adjustment coefficient is constant like price expectation coefficient over time is questionable. In real economic sense, a lot of variable can change value of the output adjustment coefficient.

Price expectation is an uncertain phenomenon especially in production economics. It is very much a common reality. But Nerlove's model does not consider such type of reality.

4.9.2 Duality Theory or Two Stage Approach

Product supply and factor demand equation consistent with a farms optimizing behaviour can be obtained by two different but equivalent approaches. One approach is formulated and derived by solving primal problem. Another approach, called the dual approach, allows one to obtain product supply and factor demand equation by partial differentiation of an indirect objective function. Duality approach does not imply any profound insights into production economic theory; nevertheless it is often quit useful because it is more convenient way to obtain supply and demand equations that is traditional (primal) approach. The dual approach is also useful in generating a functional specification for a consistent set of supply and demand equations for econometric estimation. It has become commonplace in economic literature since last decades of 20th century.

According to duality approach supply response function is not estimated by direct econometric estimation. It is derived from profit maximization conditions by using algebraic method. The duality approach is formulated on the basis of indirect profit function and cost function. These functions are obtained from profit maximization and cost minimization process. By taking the partial derivative of the indirect profit function produces output supply function with respect to output prices. Similarly the partial derivative of the indirect profit function with respect to input prices produces the input demand function. Let us consider the indirect cost function that is specified as a function of variable factor prices and quantity of all output quantities. As the same way by taking the partial derivative of the indirect cost function with respect to input prices, input demand function can also be derived (conditional factor demand).

4.9.3 A Short Illustration of Duality[8]

We know that factor demand and product supply equations can be derived from the single-product case from maximization of the profit function, let the profit function be

$$\pi \equiv PQ - \sum_{i=1}^{n} r_i x_i \tag{4.7}$$

[8] This section is made on the basis of Beatte and Taylor (1985).

Subject to production function

$$Q = f(x_1,...,x_n)$$

(4.8)

Here r_i is a vector of input prices, x_i is a vector of inputs and P is a price of output. Equation (4.7) is referred to in duality literature as a direct profit function.

An important concept of duality is the indirect profit function which is defined as the maximum profit associated with given product and factor prices. One way to obtain an indirect profit function is to solve the primal problem by substituting factor demand and product supply functions. Assuming a single-product, two-factor case;

$$x_1 = x_1(P, r_1, r_2)$$

$$x_2 = x_2(P, r_1, r_2)$$

$$Q = Q(P, r_1, r_2) \qquad (4.9)$$

Which are demand functions for x_1 and x_2 (vector of inputs) and output supply function for Q respectively. Substituting (4.9), the optimal x and, Q into (4.7) gives

$$\bar{\pi} \equiv PQ(P, r_1, r_2) - r_1 x_1(P, r_1, r_2) - r_2 x_2(P, r_1, r_2) \qquad (4.10)$$

or more compactly,

$$\bar{\pi} = \bar{\pi}(P, r_1, r_2)$$

(4.11)

Maximum profit $\bar{\pi}$, is now expressed as a function of the product and input prices. Let a general indirect profit function for the single-product, n variable factor case be denoted by

$$\bar{\pi} = \bar{\pi}(P, r_1,..., r_n)$$

(4.12)

In a profit-maximizing context, optimal levels of product and the factors are functions of product and factor prices. Thus, a profit function, that represents maximum profit associated with given product and factor prices, quite naturally, will have as arguments the appropriate prices with variable factor quantities eliminated.

Another important concept in duality theory is the envelope theory. A very important result of the envelope theorem, which is sometimes referred to as Hotelling's Lemma[9], is that

$$\frac{\delta \overline{\pi}}{\delta P} = Q(P, r_1 ..., r_n) \tag{4.13}$$

This is the product supply equation, and that

$$\frac{\delta \overline{\pi}}{\delta P} = -x_i(P, r_1, ..., r_n) \tag{4.14}$$

This is the negative of the *ith* factor demand equation.

Conceptually similar to an indirect profit function, an indirect cost function, defined as the minimum cost required for producing a specified output Q at given factor prices. The indirect cost function can be defined as

$$\overline{C} = \overline{C}(r_1, ..., r_n, Q) \tag{4.15}$$

Another important envelope theorem result, usually referred to as Shephard's Lemma, is:

$$\frac{\delta \overline{C}}{\delta r_1} = x_i^c(r_1 ..., r_n, Q) \tag{4.16}$$

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[9] Hotelling Lemma and Shephard's Lmma are specific cases of a general result called the Envelope theorem.

This is the factor demand equation for the *ith* factor conditional on the output level (i.e., conditional factor demand).

In duality approach the output supply function is derived from profit function by partial differentiation and it permits to introduce more complex functional forms, which impose less restriction in estimation procedures (Lopez, 1982).

Secondly, in duality approach the profit, the output supply and input demand are explicitly expressed as functions of exogenous variables such as output prices, variable input prices and quantities of fixed factors. Therefore another convenience of duality approach is that in the indirect profit function, simultaneous equation bias can be avoided.

Finally, Beattie and Taylors (1985) statement can be cited here regarding applicability of Duality theory "*Analysts desiring to empirically apply duality should recognize that partial differentiation of an indirect function will not give product supply or negative factor demand equations for problems characterized by certain types of risk aversion and most types of stochastic multi period problems*".

4.9.4 Price Expectations Model

In section 4.9.1, the process of adaptive price expectations has been discussed in context of Nerlovian model. In this section other expectation processes by which expectations about future prices can be formed are discussed:

i) Naïve expectations model
ii) Koyek distributed lag model
iii) Rational expectations hypothesis
iv) Alternative expectations model

i) Naïve Model of Expectations: The Cobweb Model

Ezekiel published the classic paper on "The Cobweb Theorem" in 1938 , which still stands as a landmark in the theory of prices and production. His theory was realistic and operational. In a dynamic world, past and present conditions help shape future conditions. Perhaps the simplest recursive model is the two-dimensional "Cobweb diagram," discussed by Ezekiel in 1938 .The Cobweb theory can apply only to commodities which fulfil three conditions (1) where production is completely determined by producer's response to price, under conditions of pure competition (2) the time needed for production requires at least one full period…;(3) the price is set by the supply available.

The Cobweb model is an approach to explain product response to price. The Cobweb model arises from three factors, which, if present, would result in cyclical behaviour price and quantity. *First* a time lag must exist between decision to production and the actual realization production. *Second*, producers base production plans on current or past prices. Hence realized production because of time lag, is a function of past prices. *Third*, current prices are mainly a function of current supply, which in turn, is mainly determined by production (Tomeek and Robinson, 72: 176). More precisely, planned production is a function of current prices. Assuming plans are realized, current production is a function of past prices. An alternative statement is that production plans are based on expected prices, and expected prices are a function of current and past prices.

According to Cobweb model (naïve expectations), producers would form their expectations on the basis of following equation:

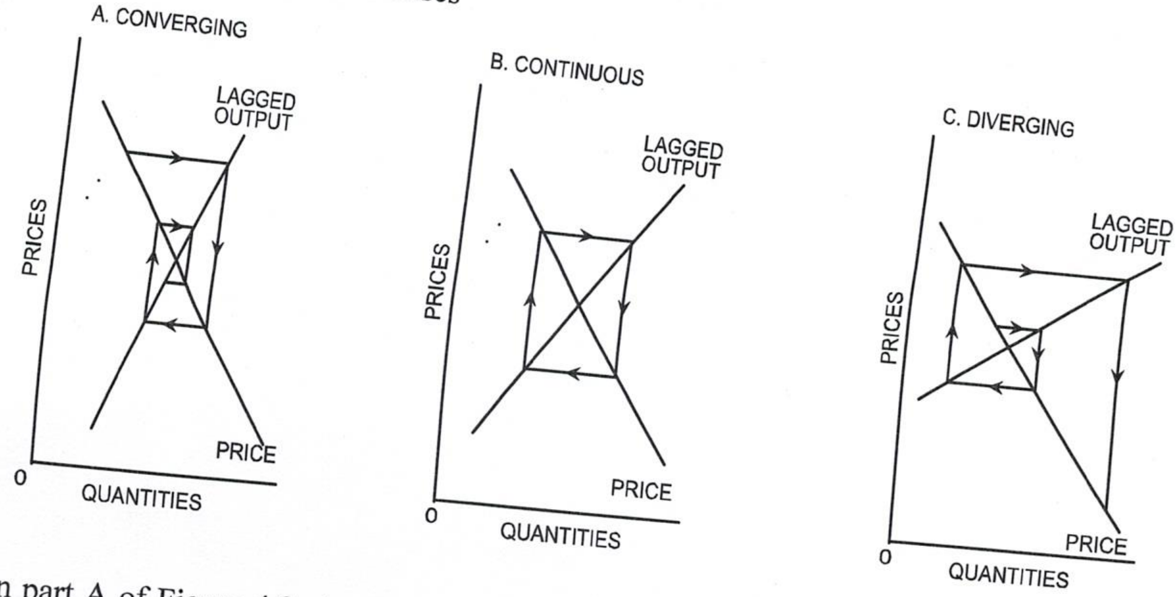
$$P_t^e = p_{t-1}$$

Here P_t^e is expected price for the next harvest, which is dependent on the last period's actual price. This expectation is related with past values of the relevant variables. This is a static or naive in the sense that it involves only one period memory and does not involve a learning process, while the Nerlovian model relates information on past prices to future expectation. The Nerlovian models are involved with past prices to future expectations also.

The Cobweb model shown in Figure 4.3(A) converges; that is, the fluctuation of price and production gets smaller and smaller as time goes on .If there is no disturbing force, the Cobweb would run down. But it is easy to draw Cobwebs that are diverging; that is, Cobwebs illustrating situations in which the fluctuations would get larger and larger as time went on. Unless some new force prevented it, these Cobwebs would "explode." It is easy to draw a Cobweb, which would result in continuous oscillation of the same magnitude.

Most discussions of Cobweb models say that a model will converge if the lagged-output curve is steeper than the price curve; that it will oscillate continuously if the slopes of two curves are equal; and that they will diverge if the price curve is steeper than the lagged-output curve. These statements are correct in the special case in which both functions are linear-either in P and Q or in $logP$ and $logQ$.

Figure 4.3: Three Linear Cases



In part A of Figure 4.3, the Cobweb converges because the lagged-output function is steeper than the price function. The slope of the price line is –a. the slope of the lagged-output line is *1/b* .If the two slopes are equal, *-ab=-1.* Part B illustrates the case of continuous oscillation because slopes of the functions are equal. The Cobweb in part C explodes because the price line is steeper than the lagged-output line. So the common statements confirmed the linear cases. These can also be demonstrated easily by algebra.

In the linear case, the two basic functions are

Price function: $P_t = -aQ_t$

$$\text{Lagged output function, } Q_{t+1} = bP_t = -baQ_t \tag{4.17}$$

Where, the subscripts refer to time periods. The prices and quantities in equation are measured as deviations from their respective "normal," or "equilibrium," values in period t . In this case we consider the Cobweb as a picture of movements around the moving equilibrium. For example, each variable may be measured as a deviation from its respective time trend. The trend is not necessarily linear (Waugh, 1969: 93). The values of the moving equilibrium are those obtained when there are no deviations from trend.

From the second equation in (4.17) we get recursively,

$$Q_{t+2} = -abQ_{t+1} = (ab)^2 Q_t$$

$$Q_{t+4} = (ab)^2 Q_{t+2} = (ab)^4 Q_t \qquad (4.18)$$

$$Q_{t+2k} = (ab)^{2k} Q_t$$

So, if $(ab)^2 < 1$, the system converges; if $(ab)^2 > 1$, the system diverges; if $(ab)^2 = 1$, the system oscillates continuously.

Waugh calls equations (4.17) and (4.18) "deterministic," or "residual-free." In actual statistical practice, they are not exact, errorless equations. Rather, they are estimates of the expected values of $P_t, Q_{t+1}, P_{t+1}, Q_{t+2}$ and so on. In practical statistical work, there are always errors of estimate (residuals).

Thus, (4.17) could be written as

$$\text{Price: } P_t = -aQ_t + u_t \qquad (4.17a)$$

$$\text{Lagged output: } Q_{t+1} = bP_t + v_{t+1} = -baQ_t + bu_t + v_{t+1},$$

Where, u is the error of estimating P_t and v_{t+1} is the error of estimating Q_{t+1}.The errors, u_t and v_{t+1} like P_t and Q_{t+1}, are measured as deviations from their respective trends. Thus the expected values of u_t and v_{t+1} are each zero, and (4.17) gives the expected values P_t and Q_{t+1}.

Stochastic equations similar to (4.18) would be $Q_{t+2} = (-ba)^2 Q_t - babu_t - bav_{t+1} + v_{t+2}$, (4.18a) and so on. Again, since the expected values of u_t, v_{t+1}, and v_{t+2} are each zero, the expected value of Q_{t+2}, Q_{t+4}, and so on, are given by equations (4.18).

The usual Cobweb model assumes that the price curve and the lagged-production curve are each fixed through time. It assumes that actual price and production fluctuate around the intersection of these stationary curves. In projecting prices and output for future years, economists will often first project trends in P and Q, corresponding to assumed trends in such shift variables as population and productivity. The Cobweb analysis indicates how the present patterns of prices and outputs are likely to affect future movements around their projected trends (Waugh, 1969:106).

ii) Koyek Distributed Lag Model

Koyek has proposed an ingenious model of estimating distributed Lag model. This model is very useful in agriculture economics in explaining producers' past economic activity by using lag values of the variables. For simplicity, with single explanatory variable an infinite distributed lag model can be written as;

$$A_t = \alpha_0 + \beta_0 X_t + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \ldots + U_t \qquad (4.19)$$

Assuming β's are all of the same sign. Koyek assumes that they decline geometrically as follows:

$$\beta_k = \beta_0 \lambda^k, K, \ldots, = 0,1, \ldots$$

Where, λ is the rate of decline or decay and $0<\lambda<1$ and $1-\lambda$ is known as the speed of adjustment. This implies that the β coefficient is numerically less than each proceeding β's. The effect of the lag variable on A_t becomes progressively smaller. Koyek ensures that the sum of β's which gives the long-run multiplier is a finite amount[10] which is i.e., $\sum_{k=0}^{\chi} \beta_k = \beta_0 \left(\frac{1}{1-\lambda} \right)$

As a result of equation (4.19), the infinite lag model may written as

$$A_t = \alpha_0 + \beta_0 X_t + \beta_0 \lambda X_{t-1} + \beta_0 \lambda^2 X_{t-2} + \ldots + U_t \quad (4.20)$$

Equation (4.20) contains a large number of parameters (infinite numbers) to be estimated and the parameter λ enters into a nonlinear form. Besides, the problem of high no linearity in parameters, the problem of degrees of freedom would prohibit estimation of any such model. Keyok suggested a way out to get rid of infinite lags, which is known as the Koyek transformation. According to Koyeks process by lagging Equation (4.20) by one period to obtain

$$A_{t-1} = \alpha_0 + \beta_0 X_{t-1} + \beta_0 \lambda X_{t-2} + \beta_0 \lambda^2 X_{t-3} + \ldots + U_{t-1} \quad (4.21)$$

Multiplying through out equation (4.21) by λ to obtain:

$$\lambda A_{t-1} = \lambda \alpha_0 + \lambda \beta_0 X_{t-1} + \lambda^2 \beta_0 X_{t-2} + \lambda^3 \beta_0 \ X_{t-3} + \ldots + \lambda U_{t-1} \quad (4.22)$$

Now, subtracting equation (4.22) from equation (4.20):

$$A_t - \lambda A_{t-1} = \alpha_0 (1-\lambda) + \beta_0 X_t + (U_t - \lambda U_{t-1}) \quad (4.23)$$

Rearranging equation (4.23):

$$A_t - \lambda A_{t-1} = \alpha_0 (1-\lambda) + \beta_0 X_t + \lambda A_{t-1} + (U_t - \lambda U_{t-1}) \quad (4.24)$$

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[10] This is because $\sum_k \beta = \beta_0 (1 + \lambda + \lambda^2 + \lambda^3 + \ldots) = \beta_0 (1/1-\lambda)$

The procedure just described is known as the koyek transformation after the Koyek transformation only three unknowns α, β_0 and λ instead of α_0 and an infinite number of β's. Though equation (4.24) contains the same estimation problems as the adaptive expectations and partial adjustment models (because autoregressive model and a lagged dependent variable exist on the right hand side).Now there is no reason to expect multicollinearity. Multicollinearity is resolved by replacing x_{t-1}, $x_{t-2,}\ldots$, by a single variable, namely A_{t-1}.

iii) Rational Expectation Hypothesis (REH)

The rational expectation formulation was originally developed by Muth (1961). It is observed from recent years that REH formulation has become popular instead of adaptive expectation model. The basic proposition is that producers are active learners who use past as well as current market information in forming their price expectation. This model is departure from the other price expectations models (like adaptive expectations hypothesis) which form expected prices as being determined solely by the past prices. Additional information on prices typically combines futures prices, government price support programs and cash prices. If producer can exploit current information efficiently and the market is perfectly competitive, then the rational expectations hypothesis is more reasonable in forming expected normal prices. In a pure economic sense, and under cost free information, the rational expectations hypothesis translates into producers anticipating expected equilibrium market prices (Lopez, 1986: 457).

The rational expectations hypothesis assumes, that individual economic agents use current available and relevant information in forming their expectations and do not rely purely upon past experiences (Gujarati, 2000: 598).Rational expectations use the model's prediction of the endogenous variables, including price, to form expectations. Instead of being based on past prices, forecasts are thus based on knowledge of a structural model of price determination, predicts of the independent variables in this model, and expectations about the policy instruments in the model (Fisher, 1982; and Eckstein, 1984). The expectations formation model is thus:

p_t^e ==*f(Model predictions / exogenous variable forecasts and expected policy changes)*

According to Rational Expectations approach, we can estimate supply response in the following way:

Consider the demand and supply equations like Cobweb model for estimating an agricultural commodity,

Supply function: $Q = \gamma_{13} + \alpha_{12} p^e + \gamma_{11} x + u_1$

Demand function: $p = \gamma_{23} - \beta_{21} Q + \gamma_{22} y + u_2$

Where, x includes either input prices (with a negative sign) or policy variables such as a fertilizer quota (with a positive sign), and y is income.

Under the rational expectations hypothesis, the expected price is the model equilibrium price at the time for which the prediction is made:

$$Q^e = \gamma_{13} + \alpha_{12} p^e + \gamma_{11} x^*$$

$$\beta_{21} Q^e = \gamma_{23} - p^e + \gamma_{22} y^*$$

Where x^* and y^* are predicted exogenous variables as seen at the time for which the price expectation is made.

We solve this system by multiplying the supply function by $-\beta_{21}$ and adding the two equations:

$$0 = (\gamma_{23} - \beta_{21}\gamma_{13}) - (1 + \beta_{21}\alpha_{12})p^e - \beta_{21}\gamma_{11}x^* + \gamma_{22}y^*,$$

$$\text{or } p^e = \frac{1}{1+\beta_{21}\alpha_{12}}\left[(\gamma_{23} - \beta_{21}\gamma_{13}) - \beta_{21}\gamma_{11}\chi^* + \gamma_{22}y^*\right]$$

Thus, if the input price x^* is expected to fall (or the fertilizer quota to rise), the expected products price p^e falls as supply is expected to rise. Replacing in the supply function, we obtain:

$$Q = \left[\gamma_{13} + \frac{\alpha_{12}(\gamma_{23} - \beta_{21}\gamma_{13})}{1+\beta_{21}\alpha_{12}}\right] - \frac{\alpha_{12}\beta_{21}\gamma_{11}}{1+\beta_{21}\alpha_{12}}\chi^* + \frac{\alpha_{12}\gamma_{22}}{1+\beta_{21}\alpha_{12}}y^* + \gamma_{11}x + u_1$$

$$\text{or } Q = \pi_0 + \pi_1 x^* + \pi_2 y^* + \gamma_{11}x + u_1,$$

Where, all variables are either observed or predicted exogenously.

The policy variable x thus has both a direct effect γ_{11} and an indirect effect, $-(\alpha_{12}\beta_{21})/(1+\beta_{21}\alpha_{12}) < \gamma_{11}$, Which is of opposite sign but smaller than the direct effect.

The exogenous variables are predicted as:

$$x^* = \phi_1 x_{t-1} + \phi_2 x_{t-2},$$

$y^* = \phi_3 y_{t-1}$,

Where ϕ's have been estimated separately. The system of equations to be estimated is:

Supply function: $Q = \pi_0 + \pi_1\phi_1 x_{t-1} + \pi_1\phi_2 x_{t-2} + \pi_2\phi_3 y_{t-1} + \gamma_{11}x + u_1$

Demand function: $P = \gamma_{23} - \beta_{21}q + \gamma_{22}y + u_2$

The supply equation contains lagged values of exogenous variables in the demand equation. But in contrast to the Nerlovian adaptive expectations model, it does not contain lagged values of the endogenous variable. Non-linear cross equation restrictions on the supply equation parameters should be imposed in order to allow identification of the structural parameters of the supply function, particularly identification of the price response coefficient α_{12}.

Rational expectations approach is more logical to the formulation of expectations than adaptive expectations. But it has some drawbacks in the sense of empirical application as well as theoretical formulation of the expectation model. Moreover, this model is too critical and not easy for understanding. The economic agents may not understand the models in which they have an incomplete understanding of the mechanisms of price determination. Further, the economic agents may not be able to use all information due to costing of acquiring information.

Empirically, it has not proved yet its superiority to more ad hoc specifications of the expectations formulation such as the Nerlovian adaptive mechanism.

iv) Alternative Expectation Model

Alternative expectations specification has been sought due to limitations and unsatisfactory performances of Nerlovian Model about price expectations. Alternative specification basically has three aspects: those that rely on econometric techniques to identify a lag structure from past prices; those that make use of additional information available to producers about future prices; whereas rational expectations approach that relies on economic theory to specify mechanism of future price formation (Sadoulet and Janvry, 95:98).

Let P_t^e is expected price at time *t*. According to econometric techniques, the following forecasting equation for P_t^e is an Autoregressive Moving Average (ARMA) process of order (PQ) in past prices as follows:

$$P_t^e = \sum_{i=t}^{p} \alpha_i P_{t-1} + \sum_{j=1}^{q} \gamma_j \varepsilon_{t-j} \qquad (4.25)$$

Where ε is white noise

The parameters of the ARMA model in equation (4.25) are estimated jointly with other structural parameters by substituting Nerlovian equation (4.3) using time series estimation techniques. Additional information on prices typically combines future prices *(P^f)*, government price support programs *(Ps)* and cash prices *(P)* in a weighted average. According to general Nerlovian equation (4.3), the expected price becomes;

$$P_t^e = \beta_1 P_t^f + \beta_2 P_t^s + \beta_3 P_{t-1}, \text{ with } \sum \beta_i = 1$$

Estimation of these weights allows determining the relative importance of future, support, and cash prices in formation of farmers' expectations. However, future prices do not fully capture government decisions, indicating that support price needs to be added separately.

Anderson, Dilon and Hardker (1977) suggested use a conditional price expectations model where the expected price is derived from a joint distribution of market and support prices. The mean support price $E(p^s)$, the standard deviations of market and support prices, σ_p and σ_{p^s} and correlations between market and support price, (p, p^s), are calculated each year on the basis of observed data for the previous five years. If p and p^s are jointly normally distributed, the mean of the conditional distribution of market prices for a given announced support price p_t^{s*} is

$$p_t^e = E(p/p^s = p^{s*}) = E(p) + corr(p, p^s)\frac{\sigma_p}{\sigma_{p^s}}\left(p_t^{s^*} - E(p^s)\right)$$

The expected market price $E(P)$ is approximated by either the lagged cash price P_{t-1} or the futures P_t^f (Sadoulet and Janvry, 1995:99).

It is observed that in empirical arenas of the relative predictive power of these alternative specifications of price expectation show that not one model dominates the rest. Different market participants seem to use different ways of forming expectations, expectation is heterogeneous, and the best approach consists of combining these different approaches (Shonk and Maddala 1985; and Sadoulet and Janvry, 1995: 99).

4.10 Conclusions

Theory of supply response works as a basis of empirical works of supply response. Each theory provides a theoretical framework that leads to formulate a empirical model from various aspects. This chapter has been discussed in the light of theoretical perspective. Econometric model of supply response has been specified on the basis of theoretical arguments. The components of every model have been used as tools, for interpreting producers' behaviour in crop cultivation process. This study identifies variables that affect output at various circumstances. These variables are own price, price of competing crops, price of inputs, technology and weather conditions. Most of previous studies in Bangladesh on supply response introduced price as only explanatory variable to measure supply response. So, concerned price and non-price variables need to be considered explaining supply response for a particular crop. Supply response may differ for the short-run versus long-run for rising and falling prices of own and competing crops. In this context, time lag is also a vital component of supply response. According to Tweeten, Pyles and Henneberry (1989) "*Any one-parameter estimation is unlikely to utilize all information and is subject to considerable error; the most reliable estimates of supply response will utilize not only direct econometric estimates at hand, but also results of previous estimates along with good judgment based on knowledge of circumstances*".

Chapter 5
Econometric Methodology-Cointegration and Error Correction Mechanism

5.1 Introduction

Several distinct methodologies have been developed in recent years for econometric analysis of time series data. In this chapter, the relevant methodological terms are discussed that are applied for empirical analysis the present study. More specifically, the dynamic relationships of rice and wheat are explained through relevant econometric modelling such as cointegration and error correction mechanism. The econometric models are most effective tools to summarize theory related study for empirical estimation and testing.

Initial step of dynamic specification is that economic theory postulates a long-run equilibrium relationship between the dependent variable and explanatory variables. The objective of any modelling strategy, which takes into account information about dependent and explanatory variables provided by the time series properties of the data, is needed.

It is observed that, time series data used in many econometric studies are creating some special problems for econometrician. It is assumed that the underlying time series data are stationary. Because, if this assumption is not present in the estimation process, the traditional hypotheses testing, which is based on small sample or asymptotic distributions of the estimates, are no longer valid. Following this problem some approaches have already been developed, that are effective for estimation and specifications of time series analysis. These tools allow the relevant economic theory to enter into the formulation of long-run equilibrium in levels while the short-run dynamics of the equation are determined. The development of cointegration and advances error correction mechanism in time series analysis have guided the tools to apply dynamics models that account explicitly for the dynamics of short-run adjustment towards long-run equilibrium.

The aim of this chapter is to illustrate recently developed econometric models to overcome the non-stationarity in data and problem to explain relationship between supply response and relevant explanatory variables such as area, price of own product and competitive products, rainfall, irrigation etc. Stationarity and non-stationarity, unit root, (Augmented Dickey-Fuller test), order of integration and error correction mechanism are discussed in this section.

5.2 Stationarity and Unit Root

According to classical regression analysis based on time series, data implicitly assume that the underlying time series are stationary. The *t* test *F* test, chi square tests are the basis of this assumption. Any time series data is said to be stationary if its mean and variance are constant over time and the value of the covariance between two-time series, not on the actual time at which the covariance is computed (Gujarati, 1995). A series is said to be stationary provided the following conditions are satisfied:

Mean: $E(Y_t) = \mu$ (5.1)

Variance: var $E(Y_t) = E(Y_t - \mu)^2 = \sigma^2$ (5.2)

Covariance: cov $((Y_t, Y_{t+k}) = E[(Y_t - \mu)(Y_{t+k} - \mu)]$ (5.3)

Conditions (5.1) and (5.2) implies that the series contains a constant mean and variance, while (5.3) tells that the covariance between any two values of Y from the series depends only on the difference apart in time between those two values *(k)*, not on the actual time *(t)* at which the covariance is computed. On the other hand a series is non-stationary if it fails to satisfy any of the conditions i.e., its mean, variance or covariance change overtime. A stationary series always moves around its mean value with constant range, and a non-stationary series moves at different points in time with changing mean, and its variance varies with sample size.

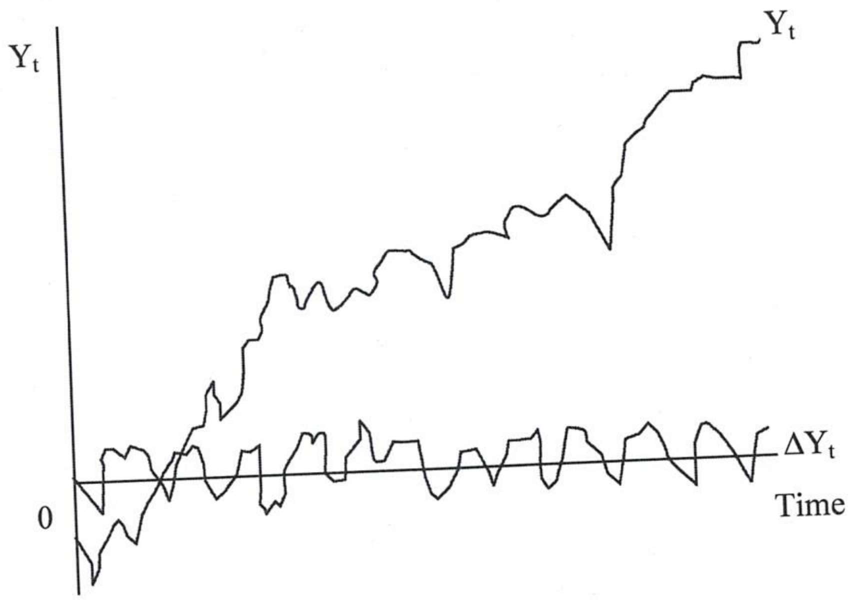
In the last two decades econometrician became careful of specific difficulties associated with analysis of non-stationarity data, which is ultimately questionable to classical assumption of stationarity of time series. Although, non-stationary data have been frequently used in empirical research works.

Let us consider the following first order autoregressive model to explain the stationarity

$$Y_t = \Phi y_{t-1} + u_t \quad t=1,...T \qquad (5.4)$$

Where u_t is assumed to be an $IID(0, \sigma^2)$. If $\Phi < 1$, the series Y_t will be stationary and if $\Phi = 1$, the series is non-stationary. Any non-stationary time series is converted into stationary by differencing in order. In this respect, how many numbers of difference are needed depends on the number of unit roots the series contains. Say a series becomes stationary after differencing *d* times, then it contains d unit roots and is said to be integrated of order d, denoted by *I (d)*. In equation (5.4), if $\Phi = 1$, Y_t has a unit root and $Y_t \sim I(1)$.

Figure 5.1: Graph of Non-stationary Series



According to Figure 5.1, initial value of $Y = 0$, it is seen that the variance of Y_t is increasing with time and it has no tendency to return its mean value. If we notice the difference operator of the series $\Delta Y_t = (Y_t - Y_{t-1})$, it shows that ΔY_t is moving around its mean value and has a finite variance.

The economic time series tend to exhibit non stationary stochastic process in the following form:

$$Y_t = \delta + \rho Y_{t-1} + u_t \qquad (5.5)$$

Where δ is a constant, u_t is the stochastic error term. Now if the coefficient of Y_{t-1} is in fact equal to 1 ($\rho = 1$). Then Y_t is said to have unit root, and, a non stationary situation (the term unit root refers to the root of the polynomial in the lag operator). In other words, Y_t could be characterized as having a unit root and a drift (random walk with a drift). A random walk is an example of non stationary time series, even if δ

equals zero. Any empirical research, which involves non-stationary time series data, has important asymptotic consequences. As a result econometric estimate and their distributions are not guaranteed to have desirable statistical properties when stationary assumption is violated. Therefore, such type of case which runs with time series data reflects the spurious regression. In this respect, the high R^2 value may be observed due to strong trends of regression line. But it does not indicate the true relationship among the variables. So it is important to explore the relationship among economic variables which true or spurious (Gujarati, 1995). Granger And Newbold (1974) argues forcefully that a regression equation is miss specified what ever the value of R^2 observed. Any research may produce spurious regression mode if adequate care is not taken over an appropriate formulation for autocorrelation structure of the error from the regression equation. Since time series data as are integrated the traditional significance tests are, therefore, usually misleading in regressions involving levels of such data. The *t test, F test* etc would tend to reject the hypotheses of no relationship when, in fact, there might be none. The fact that most variables used in traditional agriculture supply functions display a powerful trend in time series has seldom been explicitly taken into account. To avoid the following spurious correlation by introducing trend (or time) variable *t* is frequently included as one of the regressors in regressions involving time series data. However a number of time series econometricians (Nelson and Plosser 1982) have challenged this common practice. According to them, the standard practice may be acceptable only if the trend variable is deterministic and not stochastic. The trend is considered deterministic if it is perfectly predictable and not variable. In case of a stochastic trend, fluctuation in a time series is the result of shocks not only to the transitory or cyclical components but also to the trend component. Therefore, the common practice of de trending the data by a single time trend would be misleading.

5.3 Testing Method of Unit Roots

There are several methods of testing for the presence of unit root. In this section few of those, which have already usage in applied in time series econometric literature for unit root test are discussed.

Dickey-Fuller test: The Dickey-Fuller (DF, 1979) test is applied to regression in the following forms:

$$\Delta Y_t = \xi Y_{t-1} + u_t \qquad (5.6)$$

$$\Delta Y_t = \delta_1 + \xi Y_{t-1} + u_t \qquad (5.7)$$

$$\Delta Y_t = \delta_1 + \delta_t t + \xi Y_{t-1} + u_t \qquad (5.8)$$

The difference between (5.8) and other two regressions lie in the inclusion of the constant (intercept) and the trend term. Where t is the time or trend variable. The next step here is to divide the estimated ζ coefficient by its standard error to compute the Dickey-Fuller τ statistic and to refer to DF tables to see if the null hypotheses $\zeta=0$ is rejected (there is a unit root). If the computed absolute value of the τ statistics *(i.e.,* $|\tau|$*),* is less than the absolute critical values, the time series is considered to be non-stationary (Gujarati, 1995).

Augmented Dickey-Fuller (ADF) test: The ADF test is applied for test of stationarity allowing the chance of autocorrelation of error term u_t . ADF test require modifying equation (5.8) as follows:

$$\Delta Y_t = \delta_1 + \delta_2 t + \varsigma y_{t-1} + \theta \sum_{i=1}^{m} \Delta Y_{t-i} + u_t \qquad (5.9)$$

Where u_t are assumed to be identically, independently distributed random variable. This ADF test involves adding an unknown number of lagged first differences of the dependent variable to capture auto-correlated omitted variables that would otherwise enter the error term u_t .The number of lagged difference terms to be included are often determined empirically, the idea being to include enough terms, so that the error term in equation (5.9) is serially independent[11]. This ADF test statistic checks the null hypotheses that the time series has a unit root, i.e., $\zeta = 0$ under the alternative hypotheses of stationary time series. That ADF test statistics has the same asymptotic distribution as the DF statistic, so the same critical values are used.

It is important to emphasis, however, that the statistical unit root tests applied here have some limitations. For example, there are several problems related to the size and power of unit root tests, especially concerning the small sample properties of these tests. The important problem faced when applying the DF and ADF unit root tests in

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[11] Banerjee *et al.* (1993) favour a generous parameterization, since' ... the regression is free to set them to zero at the cost of some loss in efficiency, whereas too few lags imply some remaining autocorrelation.

their tendency to over-reject the null when it is true and under-reject the null when it is false, respectively[12]. This problem occurs because of the near equivalence of non-stationarity and stationarity process in finite samples.

Moreover, choosing the correct form of the ADF model is problematic and using different lag-lengths often results in different outcomes with respect to rejecting the null hypothesis of non-stationarity. There fore, unit root tests with 40 or less observation are not likely to be very powerful and failure to reject the null hypotheses of a unit root does not mean that one can accept this hypotheses. The trade-off between size and power properties of unit root tests, in particular, makes it difficult to definite statements about (non) stationarity.

5.4 Cointegration

The concept of cointegration was introduced by Granger (1981-83) and the statistical analysis of cointegrated process was organized by Engle and Granger (1987). Cointegration means that despite being individually non-stationary a linear combination of two or more time series can be stationary (Gujarati, 1998). When a linear combination of non-stationary variables is stationary, the variables are said to be cointegrated and the vector that defines the stationary linear combination is called a cointegrating vector. They show that it is quite possible for a linear combination of integrated variables to be stationary. In this case, the variables are said to be cointegrated.

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[12] Nimei. J, (2003) have cited 'Blough's that unit root tests must have either probability of falsely rejecting the null of non-stationarity when the true data generating process is a nearly stationary process or low power against any stationary alternative. More specifically, the unit root test must have power equal to its size against a near-stationary process.

Some key points of cointegration

1. Cointegration refers to a linear combination of non-stationary variables.

2. All variables must be integrated of the same order.

3. A necessary condition for cointegration is that the data series for each variable involved exhibit similar statistical properties, that is, to be integrated to the same order with linear combination of the integrated series. If the information provides that the variables are integrated to different orders, or not at all, then the specification of the model should be reconsidered (Green, 1993).

Let we consider a simple example,If the variables become stationary by differencing once, i.e. *I(1)*, then the error term originated from the cointegrating regression is stationary, i.e., *I(0)* (Hansen and Juselius,1995). Now consider the following cointegrating regression:

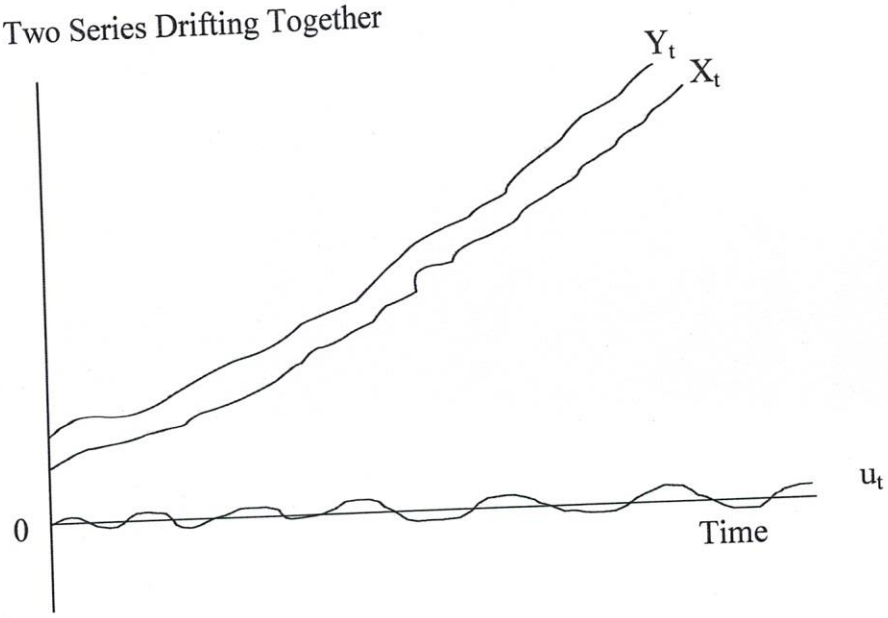
$$Y_t = \alpha + \beta X_t + u_t \qquad (5.10)$$

If the series Y_t and X_t are *I(1)*, and the error term u_t is *I(1,0)*. The coefficient β measures the equilibrium relationship between the series Y and X. The term u_t, indicates the derivation from the long-run equilibrium path of Y_t and X_t

When a time series Y_t is said to be integrated of order one, it is denoted by *I (1)*. Taking first difference of the time series leads to a non-stationary process. At the same way if the original non-stationary series has to be differenced *d'* times before it becomes stationary, the original series is integrated of order *d*, it is denoted by *I (d)*. Y_t is cointegrated of order *I(0)*,$(\therefore d=0)$,when if is stationary in level form. Following this way in the case where original series, let X_t and Y_t are integrated of order one *I(1)*, as is frequently the case with economic variables (Nelson and Plosser, 1982), consistency in ECM requires all of terms to be integrated of order zero, *I(0)*. This will only be the case if Y and X are cointegrated i,e., there is a linear Combination of X and y such as $X_t = \alpha Y + u_t$, which is stationary.

We are now to distinguish a long-run relationship between X_t and Y_t,, that is, the manner in which the two variables drift upward together, and short-run dynamics. That is, the relationship between deviations of X_t from its long-run trend and deviations of Y_t from its long-run trend (Green, 1993).

Figure 5.2: Two Series Drifting Together



The cointegration concept is depicted in Figure 5.2. Figure shows series X_t and Y_t, are clearly non-stationary trend, both series exhibit upward trends and drifting together overtime X_t and Y_t.. It implies that there exists an equilibrium relationship between X_t and Y_t. If we regress Y_t on X_t, then we get error correction term u_t. Visual inspection of error correction term illustrated in Figure 5.2 and that appears to be stationary. In this case, we can say that Y_t and X_t are cointegrated.

5.5 Error Correction Mechanism

The error correction mechanism first introduced used by Sargan and later popularized by Engle and Granger. The innovation of an ECM and advances in cointegration in particular have provided the tools to apply dynamic models that account explicitly for the dynamics of short-run adjustment toward long-run Equilibrium.

Since variables in the agricultural supply response model are cointegrated, an error correction representation would be a more appropriate modelling strategy to capture short-run and long-run dynamics in the model. When variables are cointegrated that is *(1,1),* there is a general and systematic tendency for the series to return to their equilibrium value: short-run discrepancies may be constantly occurring but they cannot grow indefinitely. This means that the dynamics of adjustment is intrinsically embodied in the theory of cointegration. The Grager representation theorem states that if a set of variables is cointegrated *(1,1),* implying that the residual of the cointegrating regression is of order *I(0),* then there exists an ECM describing that relationship. This theorem is a vital result as implies that cointegration and ECMs can be used as a unified empirical and theoretical framework for the analysis of both short-run and long-run behaviour. The ECM specification is based on the idea that adjustments are made so as to get closer to the long-run equilibrium relationship. Hence, the link between cointegrated series and ECMs is intuitive: error correction behaviour induces cointegrated stationary relationships and vice-versa (McKay, Morrissey and Vaillant, 2002:9).

Let Q_a and Q_p variables are cointegrated, and then the relationship between the two can be expressed as ECM. Assuming that Q_a 'cause' of Q_p and both variables are considered in logarithmic forms. The ECM can be written:

$$\Delta InQ_{at} = \alpha_0 + \alpha_1 \Delta InQ_{pt} + \alpha_2 ECT_{t-1} + \varepsilon_t \quad (5.11)$$

Where Δ as usual denotes the first difference operator and ε_t is a random error term. The term ECT_{t-1} is the one period Error Correction Term from the cointegrating regression. The ECM equation states that ΔQ_a is depends on ΔQ_p, and also on the Equilibrium Error Term (ECT). If the later is non-zero then the model is out of the equilibrium. Suppose ΔQ_p is zero and ECT_{t-1} is positive. This means Q_{at} is above its equilibrium value. Since α is expected to be negative, the term α_2 ECT_{t-1} is negative and therefore ΔQ_{at} becomes negative to restore the equilibrium. That is, if Q_{at} is above its equilibrium value, it starts falling in the next period to correct the equilibrium error, hence the name ECM (Gujarati, 1998:825).

There are two characteristics of an ECM.

First, an ECM is dynamic in the sense that it involves lags of the dependent and explanatory variables. It thus captures the short-run adjustments to changes in to past disequilibrium and contemporaneous changes in the explanatory variables.

Second, the ECM is transparent in displaying the cointegrating relationship between or among the variables.

The link between ECM and cointegration are exploited by the two-step procedure proposed by Engle and Granger (1987). Engle and Granger have demonstrated that the ECM corrects for any disequilibrium between variables that are cointegrated, because the sequence of the discrepancy between observed and equilibrium starts tends to decay to its mean, which is zero. The ECM specification thus provides the means by which the short-run observed behaviour of variables is associated with their long-run equilibrium growth paths. This begins with estimation of static cointegrating regression such as $X_t = \alpha Y + u_t$ and tests for cointegration.

Testing Method of Cointegration

There are two methods which are widely used to test for cointegration;

1. Engle-Granger Residual based ADF method.

2. Johanan's full information Maximum Likelihood Method (Johansen 1988; Johansen and Juselius, 1990)

1. Engle-Granger Residual Based ADF Method

Engle and Granger proposes (1987) alternative test for null hypothesis of no cointegration against the alternative of cointegration. We already know to apply DF and ADF unit test. It is a common practice to estimate a regression like equation (5.10), obtain the residuals, and use ADF test. To test the null hypothesis that Y_t and X_t are not cointegrated, in the Engle-Granger framework, it can be directly test whether error term u_t in the cointegrating regression (5.10) is stationary by using ADF test. According to this framework, testing for cointegration among a set of variables is same to test for unit root. But in this case, we find for a unit root in the static regression residuals, in the deviation from the hypothesised long-run equilibrium. Engle Granger expresses that ADF test is more convenient than any other test in most cases. Engle and Granger (1987) propose a residual based method to test the existence of the Error Correction Mechanism (ECM), and a two-step procedure to estimate the ECM. In the Engle Granger framework, for testing the null hypothesis, we directly check whether the error term u_t in the cointegration regression (5.10) is stationary, *I(0)*, applying the ADF test. Engle-Granger proposes the following modified form to test for the presence of unit root in the error term:

$$\Delta\hat{u}_t = \alpha + \beta t + \gamma u_{t-1} + \sum_{i=1}^{K}\theta_i \Delta\hat{u}_{t-i} + v_t \qquad (5.12)$$

Where $\hat{u}_t$ is obtained from the cointegrating regression in (5.10) and v_t is an identically, independently distributed error term with zero mean and constant variance σ.

The critical values for the ADF statistics, used to test the null of non-cointegration among the residuals from the cointegrating regression and it differ from those used to test the null of unit root in individual variables (Holden and Perman, 1994); adjusted critical values are presented in Philips and Ouliaris (1990), and Banerjee *et al.*, (1993).

Engle–Granger's residual-based test for the ECM is simple and this approach is commonly used in time series literature if estimates the cointegrating regression (5.10) for cointegration as first step. Now if cointegration exists, then the residuals are used in an Error Correction Model (ECM) to obtain information on the speed of adjustment to long-run equilibrium as a second step. Subsequently

$u_t = Y_t - \alpha - \beta X_t$,

From the equation (5.10) we obtain

$$\Delta Y = \gamma_0 \Delta X_t - (1-\alpha_1)[Y_{t-1} - \alpha - \beta X_{t-1}] + \varepsilon_t \qquad (5.13)$$

Here ε_t is an error term with zero mean and constant variance, γ_0 captures the short-run effect on Y of the changes in X, and β accounts for the long-run equilibrium relationship between Y and X. The term $(Y_t - \alpha - \beta X_t)$ is the divergence from the long-run equilibrium and is equal to zero when long-run equilibrium holds. At disequilibria level this term is non-zero and measure the distance the system is away from equilibrium at time *t*. The term $(1-\alpha_1)$ measures the extent of correction of that errors by adjustment in Y. The negative sign of the term $(1-\alpha_1)$ shows the adjustment moving in the direction to restore the long-run equilibrium. To overcome the spurious regression problem by differencing the variables and regressing ΔY on ΔX, results in a loss of long-run information. The term ECM incorporates the levels of the variables alongside their differences and therefore results in modelling the long-run as well as short-run relationship among the integrated series. One of the important feature of the short-run model is that all variables including the Error Correction Term are stationary, i.e., *I(0)*. This is why method based on classical OLS assumptions is appropriate for estimation.

The ECM estimation consists of two steps. *First*, the long-run equation is to be obtained by regressing the cointegrating variables. The dependent variable is selected according to theory. As only one cointegration relationship can be estimated by this method, one regression equation is estimated, and the residuals are saved for the second step. In the *second* step, the ECM is analysed by regressing the differenced variables with the lag values of the residual of the long-run regression, but this method has many drawbacks. The results of the ECM depend on the results of the first long-run equation. If there is a misspecification in the long-run equation, it will affect the results of the ECM. In addition, if there is more than one cointegrating relationship, this method cannot be employed. In fact, it has been shown that cointegrated series have an ECM representation and conversely, that ECM generates c cointegraed series. This is known as Granger representation theorem (for details, Granger, 1983 and Engle and Granger, 1987).

2. The Johansen Method

Johansen (1988) suggests a Maximum Likelihood Procedure to obtain cointegrating vectors and speed of adjustment coefficient of ECM. Identifying the number of cointegration vectors within the Vector Autoregressive (VAR) model is the basis for this procedure. To identify the number of cointegration vectors, a likelihood ratio test of hypotheses procedure is used. According to this procedure, it allows the estimation of all possible cointegrating relationships and develops a set of statistical tests to check the hypotheses about how many cointegrating vectors exist in the framework.

The following Vector Autoregressive (VAR) model is the basis of multivariate cointegration of Johansen Maximum Likelihood approach:

$$Z_t = A_1 Z_{t-1} + ... + A_k Z_{t-k} + u_t \qquad (5.14)$$

Here Z_t is an *(n×1)* vector of *I(1)* variables including both endogenous and exogenous variables, A_i is an (n×n) matrix of parameters, u_t is *(n×1)* vector of white noise errors. Each equation in (5.14) can be estimated by OLS because each variable in Z_t regressed on the lagged values of its own and all other variables in the system. Since Z_t is assumed to be non-stationary, it is convenient to rewrite (5.14) in its first-difference or error correction form as:

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + ... + \Gamma_{k-1} \Delta Z_{t-K+1} + \Pi Z_{t-K} + u_t \quad (5.15)$$

Where $\Gamma_i = -(I - A_1 - A_2 - ... - A_i), (i = 1,...k-1), and \Pi = -(I - A_1 - A_2 - ...,-A_K)$

The above specification (5.15) provides information about the short-run and long-run adjustments to the changes in Z_t by estimating Γ and Π respectively. Equation (5.14) differs from the standard first difference form of the VAR model only the inclusion of term ΠZ_{t-K}. This term shows about the long-run equilibrium relationship between the variables in Z_t. Information about the number of cointegrating relationship among the variables in Z_t is given by the rank of the matrix Π. If the rank of the Π matrix, r, is $0 < r < n$ there are linear combination of the variables in that are stationary. The matrix can be decomposed into two matrices α and β such that $\Pi = \alpha\beta'$, where α is the error correction term and measures the speed of adjustment in ΔZ_t and β contains r distinct cointegrating vectors i.e., the cointegrating relationships between the non-stationary variables. Johansen (1988) introduces the reduced rank regression procedure to estimate α and β matrices and specifies tests to test the number of distinct cointegrating vectors. It is applicable to test hypotheses about the matrices. He shows that the maximum likelihood estimates of β can be estimated as the Eigen vector and the related Eigen values are obtained by solving the following equation:

$$| \lambda S_{KK} - S_{K0} S_{00}^{-1} S_{0K} | = 0 \quad (5.16)$$

Where S_{00} is the residual matrix obtained by regressing on its differences, i.e., ΔX_{t-1}, ..., ΔX_{t-K+1}, S_{kk} is the residual matrix obtained by regressing X_{t-k} on its lagged differences, i.e., ΔX_{t-k+1}, S_{k0} and S_{0k} are cross products of residual matrices S_{kk} and S_{00};

Some variables in the model which are *I(0)* and are insignificant in the long-run cointegrating space but affect the short-run model, equation (5.15) can be written as:

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \Pi Z_{t-K} + \Psi D_t + u_t \qquad (5.16)$$

Here D_t indicates the *I(0)* variables. These are frequently included to take account of short-run shocks and treated as policy intervening variables. In the model these variables are typically included as dummy variables.

Two Likelihood Ratio (LR) tests are formulated for detecting the presence of a single cointegrating vector.

Firstly, the trace test statistic is:

$$\lambda_{trace} = -2InQ = -T\sum_{i=r+1}^{p} In(1-\lambda_i) \qquad (5.17)$$

This tests the null hypothesis of at most r cointegrating vectors against the alternative hypothesis of greater than r.

The second test is known as the maximal-eigenvalue test which is as follows:

$$\lambda_{\max} = -2In(Q : r \mid r+1) = -TIn(1-\lambda_{r+1}) \qquad (5.18)$$

This is the test of the null hypothesis of r cointegrating vectors against the alternative hypothesis that of is $r+1$. Monte Carlo has derived the critical values for these tests, simulated and tabulated by Johansen (1988) and Osterwald-Lenum (1992).

Johansen procedure can also be used as a means of alternative test for unit root, which tests the null of stationarity rather than non-stationarity.

The common feature of error correction formulation of (5.15) is that it includes both the differences and the level of the series in the same model. So there is no loss of information about the long-run equilibrium relationship between the variables. It is needed to mention here that a number of issues need to be considered before introducing this methodology. *Firstly*, the endogenous variables which is included in the VAR are all *I(1)*. *Secondly*, the additional exogenous variables included in the VAR explain the short-run behaviour, these are need to be *I(0)*. Thirdly, the selection of lag length k (order) in the Vector Autoregressive (VAR) is important and the Akaike Information Criterion (AIC), or Schwartz Information Criterion (SBC) are frequently used. But information criteria may not essentially adequate when errors contain moving average terms (Cheung and Lai, 1993).

5.6 Testing Procedure for Unit Roots, Cointegration and ECM

Since the validity of the error correction specification requires the existence of a long-run relationship or cointegration between the variables concerned, the modelling strategy begins with tests for the existence of a cointegrating vector involving the variables of interest.

A number of methods for testing for cointegration have been proposed in recent time series literature. However, the first step in the analysis of cointegration is to investigate stationarity of the time series involved, i.e., the integration of order of univariate time series.

At the formal level, stationarity can be checked by finding out if the time series contains a unit root. The recent voluminous literature on unit roots has provided a variety of possibilities of detecting these in observed time series. The Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests can be used for this purpose. The DF test is describes as follows;

$$\Delta Y_t = \xi Y_{t-i} + u_t$$

$$\Delta Y_t = \delta_t + \xi Y_{t-i} + u_t$$

$$\Delta Y_t = \delta_t + \delta_2 t + \xi Y_{t-i} + u_t \qquad (5.19)$$

Where, t is the time or trend variable.

The estimated ξ coefficient by its standard error to compute the Dickey-Fuller τ statistics and then check Dickey-Fuller tables to see if the null hypothesis $\xi = 0$(there is a unit root) is rejected. If the computed absolute value of the τ statistics is less than the absolute critical values, the time series is considered as non-stationary (Gujarati 1995). However, Dickey Fuller tables for critical values of the τ statistic are not totally adequate[13]. Therefore, they have considerably extended through Monte Carlo simulations by MacKinnon (1991), and Davidson and MacKinnon (1993). MacKinnon (1996) provides a computer program to calculate numerically highly accurate critical values at any desired level.

In the case that the error term u_t is auto-correlated, one modifies (5.19) as follows:

$$\Delta Y_t = \delta_t + \delta_2 t + \xi Y_{t-i} + \sum_1^m \Delta Y_{t-1} + u_t \qquad (5.20)$$

[13] The DF test suffers from one serious disadvantage: the test statistic does not follow any standard tabulated distribution, either in finite samples or asymptotically.

We then apply the ADF test. Thus, the ADF test is comparable to the simple DF test but it involves adding an unknown number of lagged first differences of the dependent variables to capture auto-correlated omitted variables that would otherwise enter into the error term u_t. The number of lagged difference terms to be included is often determined by empirically, the idea being included enough terms so that the error term in (5.20) is serially independent. The ADF statistic has the same asymptotic distribution as the DF statistic, so the same critical values can be used.

If non stationariy can be rejected, standard regression methods can be applied safely. Otherwise, one may choose to transform the series to stationarity, or one may investigate cointegratiing relationships between data series, which if present could justify regression involving the levels of the variables (Harries, 1995). Therefore, having established that all series are integrated of the same order, tests for cointegration are undertaken, and the nature of cointegrating vectors explored. Tests for unit roots are performed on univariate (single) time series. In contrast, tests for cointegration are performed among a set of time series. cointegration deals with the relationship among group of variables, where each has a unit root. The null hypothesis to be tasted is no cointegration, i.e., spurious regression.

Two broad approaches for testing for cointegration have been developed. The Engle and Granger (1987) method is based on assessing whether single equation estimates of the equilibrium errors appear to be stationary. Therefore, Engle and Granger tests are closely related to some of the tests suggested by Fuller (1979, 1981). The second approach, due to Johansen (1988, 1995) and Stock and Watson (1988), is based on the Vector Auto-Regression (VAR) approach.

The study applies the ECM method developed by Engle and Granger. The Engle Granger approach for testing cointegration is to construct a test statistics from the residuals of a cointegraing regression. Where the original series are integrated of order one, *I(1)*, as is frequently the case with the economic variables (Nelson and Plosser, 1982). Cointegration requires the residual terms of two or more time series to be integrated of order zero, *I(0)*. With m time series $Y_1, \ldots, Y_m$, each of which is *I(1),(integrated of order 1),* two forms of the cointegrating regression equations are:

$$Y_{t1} = \zeta_0 + \sum_{i=2}^{m} \zeta_j Y_{ij} + u_t \qquad (5.21)$$

$$Y_{t1} = \zeta_0 + \zeta_t + \sum_{i=2}^{m} \zeta_j Y_{ij} + u_t \qquad (5.22)$$

Equation (5.21) is without trend and equation (5.22) is with trend. A test of no cointegration is given by a test for a unit root in the estimated residuals $\hat{u}_t$. The procedure is essentially the same as the DF and ADF tests. The ADF regression equation is:

$$\Delta u_t = \eta^* u_{t-1} + \sum_{J=1}^{p} \eta_J \Delta \hat{u}_t + v_t$$

Test statistics is a *t*-ratio test for $\eta^*=0$ (the τ test).If this null hypotheses cannot be rejected (against the alternative $\eta^* < 0$), then the variables are not cointegrated. If the null hypotheses is rejected, then the conclusion would be that the estimated u_t is stationary (i.e. does not have a unit root), and therefore, the time series $Y_1, \ldots, Y_m$, despite being individually non-stationary, are cointegrated.

The alternative test for the existence of a unit root in the residuals of the cointegrating regression is that suggested by Phillips (1987) and extended by Perron (1988) and Phillips and Perron (1986). Rather than taking account of extra terms in data generating process by adding them to the regression model, a non-parametric correction to the *t-test* statistic is undertaken to account for the autocorrelation that will be present. That, is while the DF procedure aims to retain the validity of tests based on white-noise errors in the regression model by ensuring that those errors are indeed white noise, the Phillips–Perron (PP) procedure acts instead to modify the statistics after estimation in order to take into account the effect that auto correlated errors will have on the results (Banerjee *et al.*1993). Sources of critical values for the PP test include Phillips and Ouliaris (1990), and MacKinnon (1991).

The testing procedures discussed above involve actually estimating the cointegrating vectors. If the null hypothesis of no cointegration is rejected, the second step uses the lagged residuals from the cointegrating regression as an error correction term in a dynamic, first difference regression. One can then "test down" to find a satisfactory structure. Because of complexity of dynamic relationships, the structure of ECM may be complicated. A major decision is the choice of lag length. Ordinary least squares can, however, be used throughout, and Engle and Granger (1987) show that it yields consistent estimators for all the parameters.

5.7 Conclusions

This chapter provides a discussion empirical methodology which is applied in study. Methodologies include testing unit root, cointegration and ECM. One of the key objectives of this study is to avoid spurious regression. As a first step to avoid this problem, it is important to test for the presence of unit roots among the series. In this respect, DF and Augmented Dickey- Fuller test are used.

The framework of cointegration testing procedures developed by Johansen (1988, 1995) and Johansen and Julious (1990, and 1992) can be applied to evaluate long-run relationships among the variables. Augmented Dickey-Fuller residual tests and Johansen's (1988) maximum likelihood estimation method of reduced rank can be used to test the null of no cointegration. The residual-based tests are analogous (similar way) to univariate tests used to specify the order of integration of the variables, but it is the residuals that are tested. One of the major limitations of the residual-based method is that it implies a unique cointegrating vector. So if the cointegrating regression has more than two variables, there may be more than one cointegrating vector. In this respect, the use of residual-based approach is not appropriate. As a result Johansen's method which allows the estimation of all the possible cointegrating relationship exists among the variable is preferred. When variables are cointegrated, it implies that there exists an ECM. In fact, ECM is a generalization of the partial adjustment model. This theorem is a vital result as implies that cointegration and ECMs can be used as a unified empirical and theoretical framework for the analysis of both short-run and long-run behaviour.

Chapter 6
Data Description and Specification of Variables

6.1 Introduction

The success of any econometric analysis ultimately depends on the availability of the appropriate data. This chapter discusses the nature, sources and limitations of the data. The empirical analysis of this study has been conducted with a sample of annual data covering major crops of Bangladesh from 1972-73 to 2003-04. The data utilized in the this study are obtained from various publications of the Bangladesh Bureau of Statistics (BBS)

The time series data on annual price of rice and wheat prices in Bangladesh are obtained from various issues of BBS of the years 1979, 1982, 1990, 2000 and 2001. Area irrigated by different crops (rice and wheat) is collected from Statistical Year Book of 1979, 1983-84, 1991 and 2001.

Data on rice and wheat area and production are obtained from Agriculture Statistical Year Book of 1998, Statistical year Book of 1999, and 2001 and Economic trend of 1998, published by Bangladesh Bank. Relevant data included at the end of this chapter in Appendix.

A list of variables of area, production, price irrigated area and yield rate that has been selected for this study included in Table 6.1.

Table 6.1: List of Variables

Variable	Variable description
InAa	Total area of aus rice
InQa	Total production of aus rice
InPa	Price of aus rice
InIa	Irrigated area of aus rice
InYa	Yield rate of aus
InAm	Total area of aman
InQm	Total productionof aman rice
InPm	Price of aman rice
In Im	Irrigated area of aman
InYm	Yield rate of aman rice
InAb	Total area of boro rice
InQb	Total production of boro rice
InPb	Price of boro rice
InIb	Irrigated area of boro rice
InYb	Yield rate of boro rice
InAw	Total area of wheat
InQw	Total production of wheat
InPw	Price of wheat
InIw	Irrigated area of wheat
*InYw**	Yield rate of wheat

6.2 Specification of Variables

Variables, those are included in this research are discussed as follows:

Productiont: production (Output) of the concerned crop is one of the decision-making variables in crop production in Bangladesh. Farmer always maximizes their crop output towards food self-sufficiency and profit maximization in comparison to other competitive crops. In this study price, production, irrigated area and yield rate have been used as explanatory variables, which are responsive to area allocation of concerned crop.

Selection of price: Price has an allocative influence on resources and is most important for policy purposes. In fact, farmers take planting decisions with respect to expected prices prevailed during the post harvest period. This expected price is generated on the basis of different expectation generators such as realized prices; last period expected price, variations in prices and the prevailing prices at different points in time in the preceding year. Harvest prices of wheat and rice have been taken into consideration for the reason that whole sale and retail price may not reflect what farmers actually receive, because farmers are usually set at a considerably higher level than what farmers get. Moreover, in case of Bangladesh rural farmers sell lion portion of their products at immediate post harvest periods price. Considering these harvest prices of crops has been selected for analysis. In this study, nominal harvest prices of agricultural products have been used, because of time saving and easy calculation nominal prices are used.

Rice and wheat area: Area of the crop plays important role in decision-making variable of farmers. This variable has been used as dependent variable, which is responsive to prices, output, yield, irrigated area and prices of concerned crops. Aman area (Am), aus area (Aa), boro area (Ab) and wheat area (Aw) have been taken for this study. These are actual planted area of different types of rice and wheat measured in '000' acre.

Prices of competitive crops: Wheat and boro rice are grown almost at the same period from November to April in Bangladesh. In addition, wheat and boro rice are cultivated at the same land and both crops are highly irrigation based. So, wheat and boro rice are competitive products with each other. Harvest prices of wheat and boro rice has been used as competitive prices measured in per metric tonnes.

Yield rate: Yield per acre in metric tonnes of the crop has been used in this study as yield rate of rice and wheat has been calculated on the basis of the following formula:

$$\text{Y. R.} = \frac{\text{Pr}\,oduction}{Area}$$

Irrigated area by different crops: Irrigation has a significant impact on rice and wheat production. Wheat is specifically grown in areas, where adequate irrigation facilities are available. It is hypothesized that improvement of irrigation facility may increase wheat acreage.

Aus and boro rice are growing during mid-March to mid August and November to end of March respectively. In Bangladesh, more than 85 percent of total annual rainfall occurs between Junes to September.

So, irrigation and water availability are crucial factors for growing aus, boro and wheat. In case of aman rice, irrigation is less important because aman is grown during the rainy season. But lack of rainfall in proper time, it is not always possible to sustain without irrigation. Irrigated area by different crops are measured in '000' acres

6.3 Data Description of Aus Rice

Table 6.2: Annual Rate of Growth (percent) in Area, Production and Yield (acre) of Aus Rice

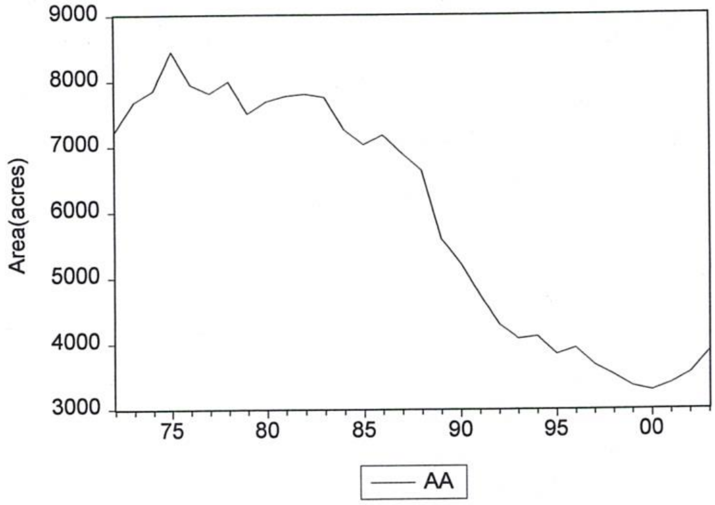
Crop	1972-73 to 1980-81			1981-82 to 1990-91			1991-92 to 2000-01		
Aus	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
	.68	4.7	3.8	-4.2	3.1	1.1	-3.6	-1.7	1.9

Note: Computed from the data Appendix 6.1.

6.3.1 Area of Aus

Area under aus increases at 0.68 percent during the period of 1972-73 to 1980-81. Growth of aus area shows a downward trend in Figure 6.1. It is seen from Table 6.2; area under aus rice is gradually decreasing at decreasing rate from the 1980s to the end of the 2000s. Area under HYV aus is increased during the 1990s and the 2000s by 1.8 percent and 0.35 percent respectively, while area under local varieties decline in the 1990s and 2000s. This is mainly due to the adoption of HYVs by farmers through replacement of local rice varieties

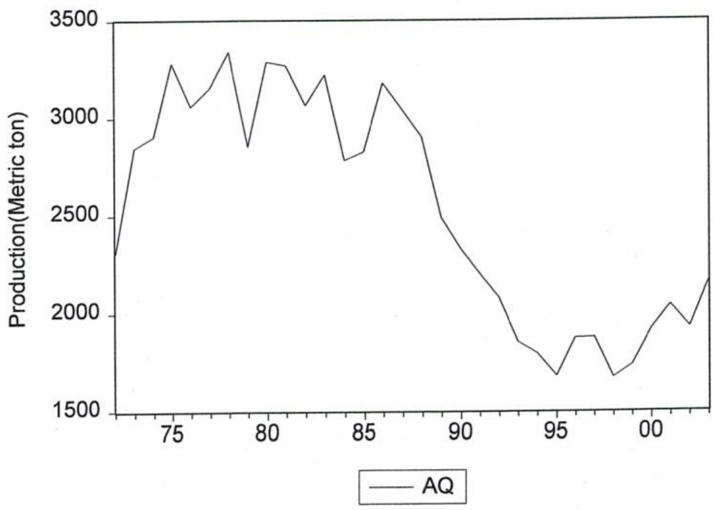
Figure 6.1: Trend of Aus Area



6.3.2 Production of Aus

Aus rice production declined during the period 1981-82 to 2000-01, mainly owing to decreasing areas of total aus rice, though aus rice production shows increasing trend (4.7 percent) during 1972-73 to 1980-81. High Yielding Variety (HYV) aus has shown positive trend at slow growth rate during the period 1991-92 to 2000-01 and it continue till 2003-04. As a result, aus production is registered annual growth rate of 1.4 percent during the 2000s against declining trend in the 1980's (-3.1 percent) and 1990's (-1.7 percent). Figure 6.2, shows a downward trend aus production line.

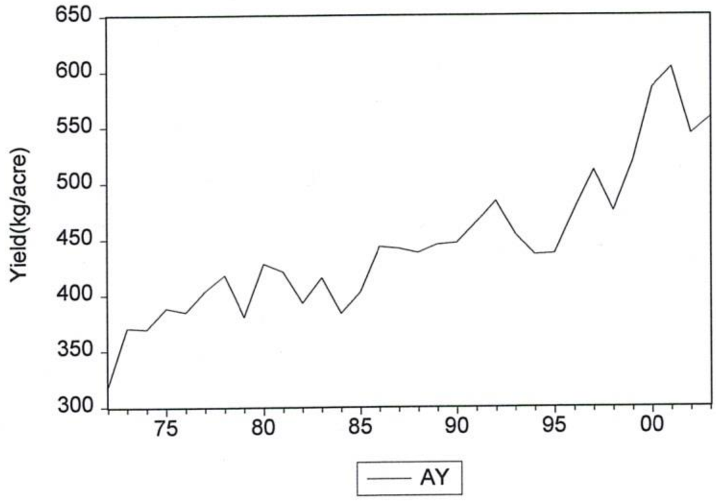
Figure 6.2: Trend of Aus production



6.3.3 Yield of Aus

Aus rice shows most significant increase in yield, at 34 percent during the period 1972-73 to 1980-81 (annual average 3.8 percent). This is because of technological adoption in crop production strategy. The rate of increase in aus rice yield is 1.1, 1.9 and 3.1 percent during 1980s, 1990s and 2000s respectively. Yield of aus rice shows an upward (moving slowly) trend in Figure 6.3.

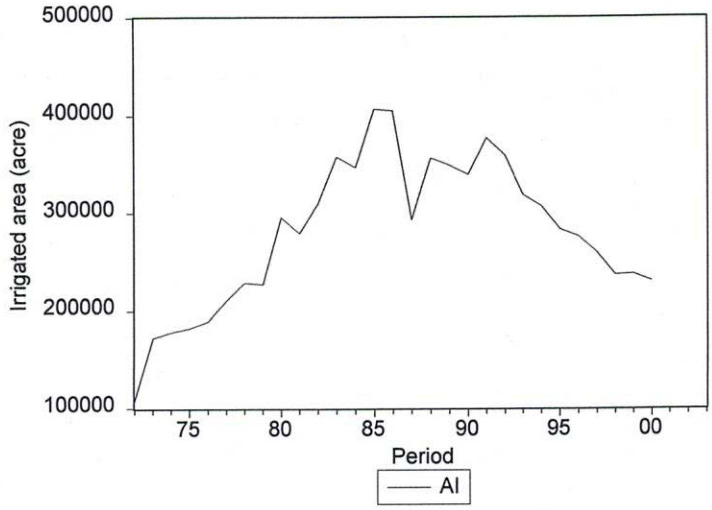
Figure 6.3: Trend of Aus yield



6.3.4 Irrigated Area of Aus

At initial level irrigated area shows an upward trend in Figure 6.4. Irrigated area under aus rice increases since 1972-73 to 1984-85 continuously. It is noticeable that irrigated area increased sharply consecutively two years 1985-86 and 1986-87, then falling remarkably till the end of the 20^{th} century. Annul growth rate of irrigated area on an average is 4 percent during the period of 1972-73 to 2003-04.

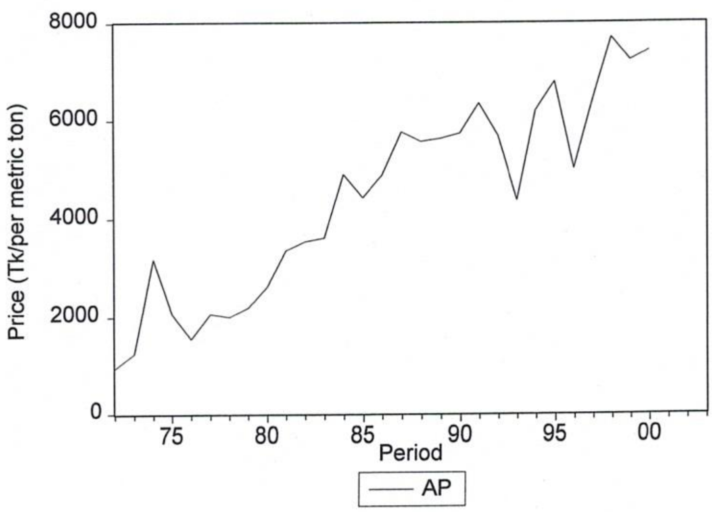
Figure 6.4: Trend of Irrigated Area of Aus



6.3.5 Price of Aus

Growth trend of price of aus rice has shown in Figure 6.5 over the period 1972-73 to 2000-01. The nominal prices have shown an average annual growth rate of 18 percent. The price variable shows an upward trend over the period. It is seen from Table 6.1 that at the beginning of the 1970's (1972-73 to 74-75) price level is increased sharply. This is mainly due to effect of independence war and some external causes. Though later price level of aus rice has been increased remarkably till the mid 1990s. It is seen that price level of aus is highly fluctuating due to bumper production and devastating flood during the period 1992-93 to 2000-01.

Figure 6.5: Trend of Aus Price



6.4 Data Description of Aman Rice

Food grain in Bangladesh consists of major cereals of rice and wheat. Major cereals i.e., rice and wheat account for over 99 percent of the total cereals area. Aman, the major cereals, occupies about 93.16 percent of the total cereals area. Three varieties of aus, aman and boro rice occupy area of 18.56, 47.18 and 27.45 percent respectively. Three-fourth of aus rice is local; the rest one-fourth is HYV. Out of total aman rice 57.33 percent is local while 37.15 percent is HYV. The major portion of (78.29 percent) the boro rice is HYV.

Aman is the major rice crop in Bangladesh and provides about 45 percent of Bangladesh's annual rice production (Deb, Billah and Das, 2004:12). Aus rice contributes only 5 percent to total rice production.

Boro production gradually reaches to the highest production level in 2003-04 (Deb, Billah, 2004; 9). It is noteworthy to report that since 1998-99 boro crop has had a larger share in total production than aman rice, which is historically Bangladesh's principal crop. This indicates a structural shift in Bangladesh's rice production from a largely weather influenced crop to an irrigated crop, which is much more sensitive to the quality of public policy and Governance than the vagaries of nature (Deb, Billah and Das, 2004:9).

Table 6.3: Annual Rate of Growth (Percent) in Area, Production and Yield (per acre) of Aman Rice

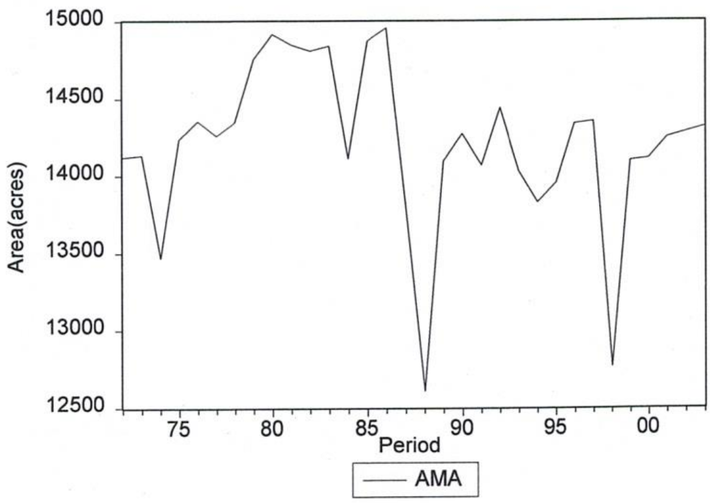
Crop	1972-73 to 1980-81			1981-82 to 1990-91			1991-92 to 2000-01		
Aman	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
	.63	4.47	3.6	-0.1	1.7	2.6	-0.4	0.8	1.2

Note: Computed from the data Appendix 6.2.

6.4.1 Area of Aman

Area under aman rice increases on an average 0.5 percent in the period 1972-73 to 1981-82. Later, area of aman rice decrease at (-0.1) in 1980s and (-0.4) percent in 1990s. The area under HYV aman grow has increased while the area under local varieties broadcast aman decline in the 1980s, 1990s and 2000s. This is mainly due to the adoption of HYVs by farmers through replacing local rice varieties. A trend of aman area is depicted in Figure 6.6. which is highly fluctuating.

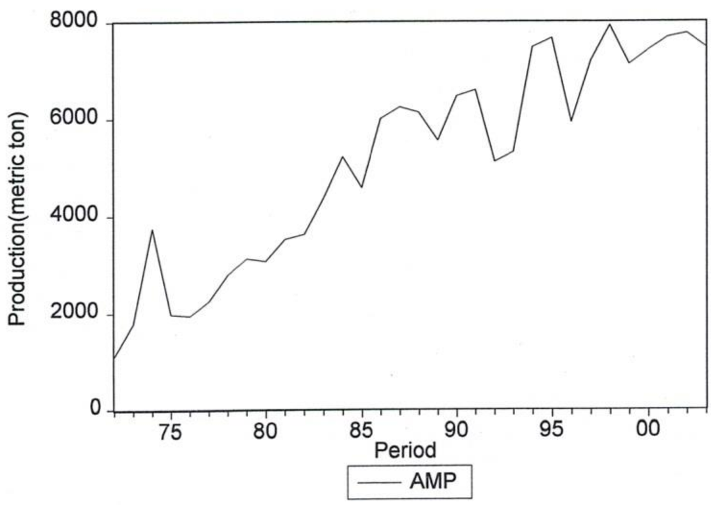
Figure 6.6: Trend of Aman Area



6.4.2 Production of Aman

Growth rate of aman production in the 1980s, 1990s and 2000s is 1.7 percent, 0.8 percent and 3.5 percent respectively. In the 1970s it is 2.6 percent. Table 6.3 expresses area under aman increased by 0.52 percent during the period 1972-73 to 1981-82. It is noticeable that in this period growth rate of production is higher than increased in area. So, yield of aman is upward trend during this period. Production of Broadcast aman is remarkably decreased by 6.5 percent in period 1972-73 to 1981-82, while HYV aman sharply is increased by 8.6 percent during the period. This is because replacement of Broadcast aman area by HYV aman area. As a result, total aman production growth is positive. During the period 2001-02 to 2003-04, area under aman rice has increased by only 0.3 percent, while average yield of aman rice increased by 3.3 percent. Thus, increase in average yield of aman is the driving force behind increase in aman production while is 3.6 percent. An upward trend of aman production delineate in Figure 6.7.

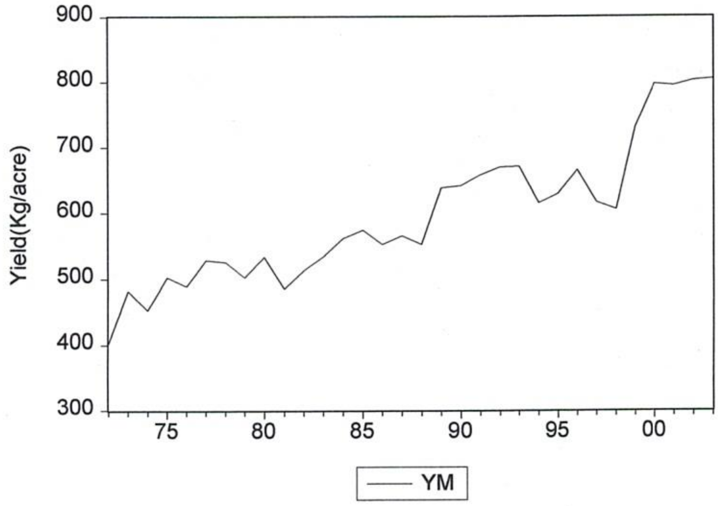
Figure 6.7: Trend of Aman Production



6.4.3 Yield of Aman

Yield of aman increases by 2 percent during period 1972-73 to 1981-82. Yield of all types of aman rice has increased except local transplanted aman, which is decreased during the period 1972-73 to 1982-83. This trend is continuing till the 2000s which is reflected in Figure 6.8. During 1991-92 to 2000-01, average yield is low in comparison to any other period.

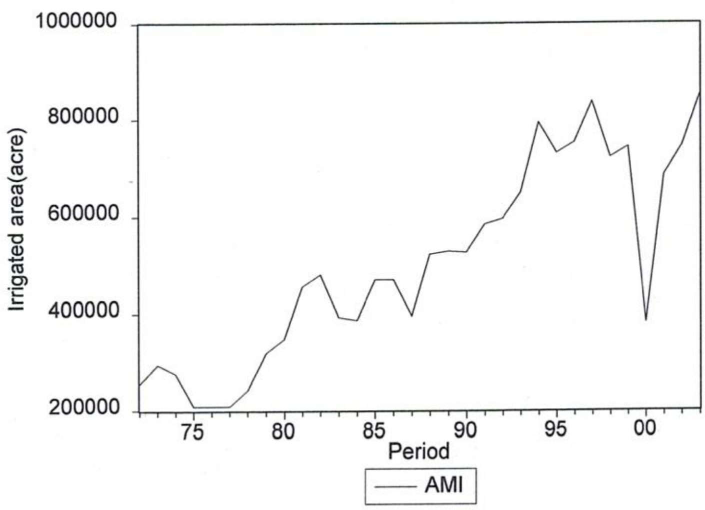
Figure 6.8: Trend of Aman Yield



6.4.4 Irrigated Area of Aman

Irrigated area shows an upward trend over 1972-73 to 2003-04 in Figure 6.9. After independence of Bangladesh, irrigated area under aman rice has been increased gradually, but during the period of 1975-76 to 1977-78 it is decreased remarkably. This is mainly due to policy transition of input distribution by Bangladesh government. It is also seen from Table 6.2, that area of aman rice is almost stagnant during 1975-76 to 1978-79, and irrigated area under aman rice is gradually increased until starting of 21st century.

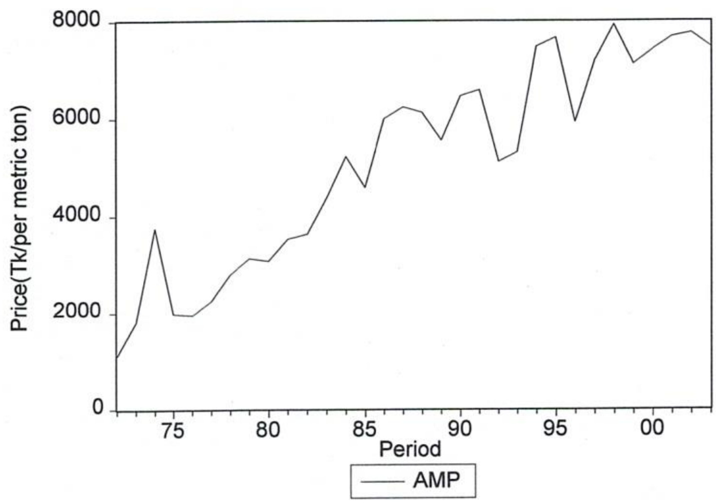
Figure 6.9: Trend of Aman Irrigated Area



6.4.5 Price of Aman

Price of aman rice is shown in Figure 6.10 (over the period 1972-73 to 2003-04). In this study nominal harvested price has been considered as price variable. The price variable shows an upward trend over the period in Figure 6.5. It is seen that price of aman rice is increased continuously over the period. It is also seen that price level of aman rice is sharply increased at the period of 1974-75. This happens due to eco-political phenomena after independence of Bangladesh. This is not considered in this study. It is clear from the data table (Appendix 6.2) that price level of aman rice is highly fluctuating due to bumper production and inversely devastating flood at that particular period 1973-74 and 1974-75.

Figure 6.10: Trend of Aman Price



6.5 Data Description of Boro Rice

Table 6.4: Annual Rate of Growth (percent) in Area, Production and Yield (per acre) of Boro Rice.

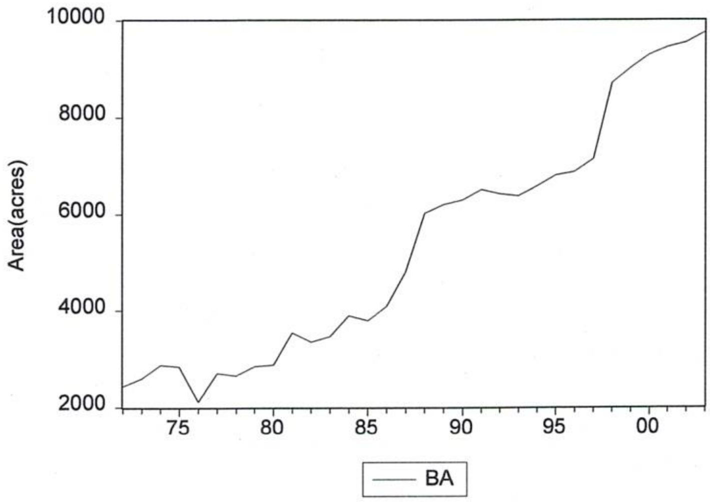
Crop	1972-73 to 1980-81			1981-82 to 1990-91			1991-92 to 2000-01		
boro	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
	1.97	2.78	.6	8.1	8.2.	0.1	4.5	7.0	2.5

Note: Computed from the data Appendix 6.3

6.5.1 Area of Boro

According to table 6.4, area under boro rice is increased at a slower growth rate 1.97 during the period of 1972-73 to 1980-81. But later, area under boro rice increased at an average rate of 8.1, 4.5 and 2.2 percent in the 1980s, 1990s, and 2000s respectively. Area under HYV boro is increased while the area under local varieties decline in the 1990s and the 2000s. This happens mainly due to the adoption of HYVs by farmers through replacement of local rice varieties. A sharp upward trend of boro area is depicted in Figure 6.11.

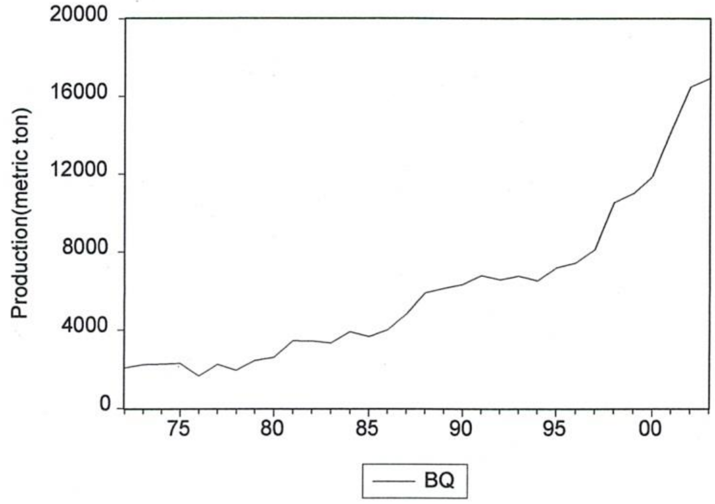
Figure 6.11: Trend of Boro Area



6.5.2 Production of Boro Rice

Growth rate in production of boro rice is 8.2, 7.0 and 4.4 percent during the 1980's, 1990's, and the 2000's, respectively. Growth in total rice production at the end of 20^{th} century (1980s and 1990s) is mainly due to the growth in boro rice production (Deb, Billah and Das 2004). Production of boro rice is increased by 2.78 percent and its share in total rice is increased during the period 1972-73 to 1980-81. Figure 6.12 shows an upward trend of boro production over the period 1972-73 to 2002-03.

Figure 6.12: Trend of Boro Production

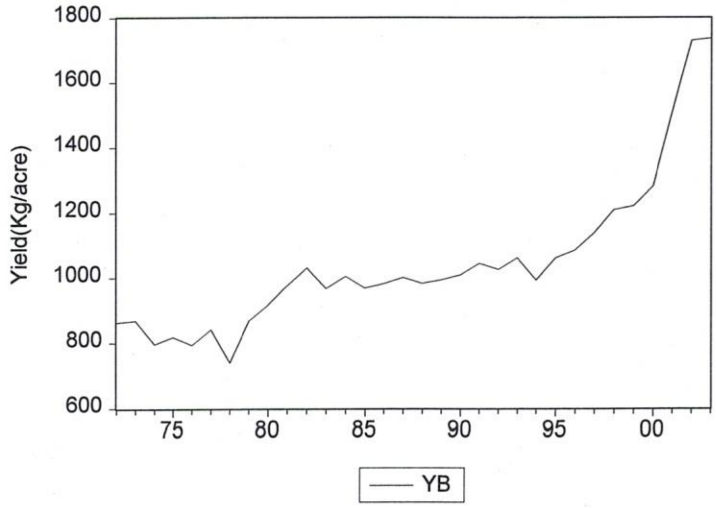


6.5.3 Yield of Boro Rice

Yield of all rice crops increases during the last 4 decades (since 1970s) except local transplantation of aman. Yield of boro rice shows upward trend in Figure 6.13 during this periods. Yield of boro rice is increased by 0.6, 0.1, 2.5 and 2.1 percent in the 1970s, 1980s, 1990s and 2000's respectively.

Year to year yield may fluctuate due to climatic factors, variation in input/output prices, managerial skills of producers, and controllability of the technology of production.

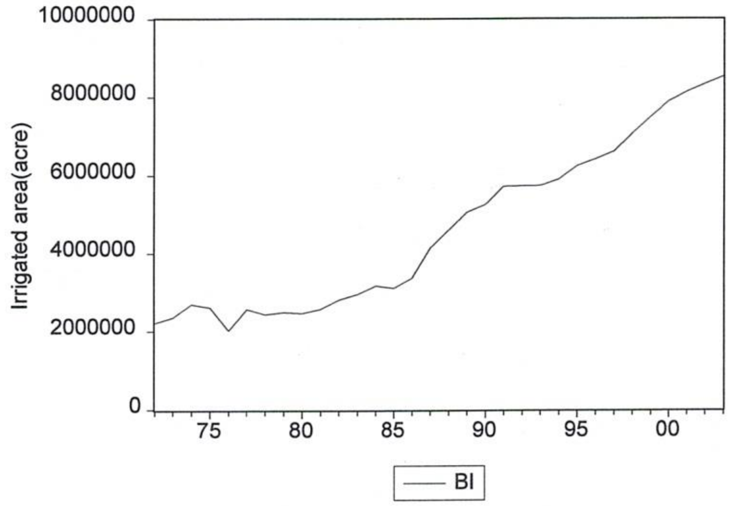
Figure 6.13: Trend of boro rice yield



6.5.4 Irrigated Area of Boro

Irrigated area under boro rice shows an upward trend over the period 1972-73 to 2003-04 in Figure 6.14. It is also seen that irrigated area under boro rice significantly increases due to vast cultivation of boro rice in the country during the 1980s. According to data table (Appendix 6.3 and Table 6.4) that yield rate of boro has been increased remarkably.

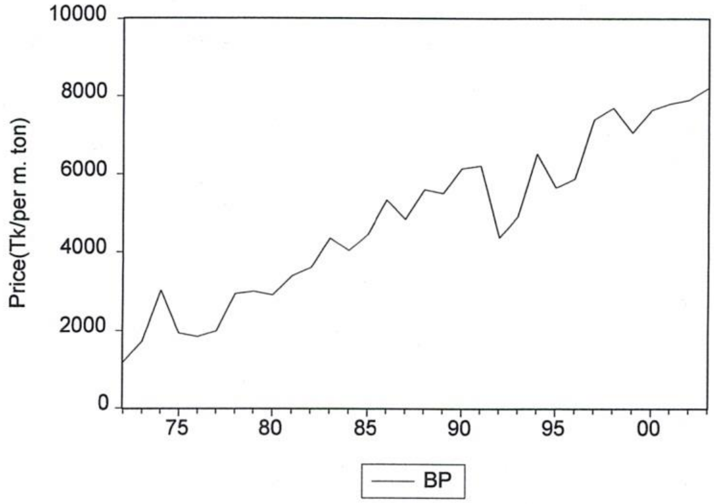
Figure 6.14: Trend of Irrigated Area of Boro Rice



6.5.5 Price of Boro Rice

Price of boro rice shows an upward trend over the period in Figure 6.15. It has increased since 1972-73 continuously. It is mentionable that price of boro is increased sharply during 1974-75 due to eco-political instability in the country which is more politically explainable than economic phenomenon. After the period of 1977-78 price level of boro rice increases significantly (Appendix 6.3) till 1991-92. This might be happening due to increase in food grain as well as input increase cost and finally commercialization of agriculture. But there is found significant decrease of the price level during the years 1992-93 to 1993-94.

Figure 6.15: Trend of Boro Price

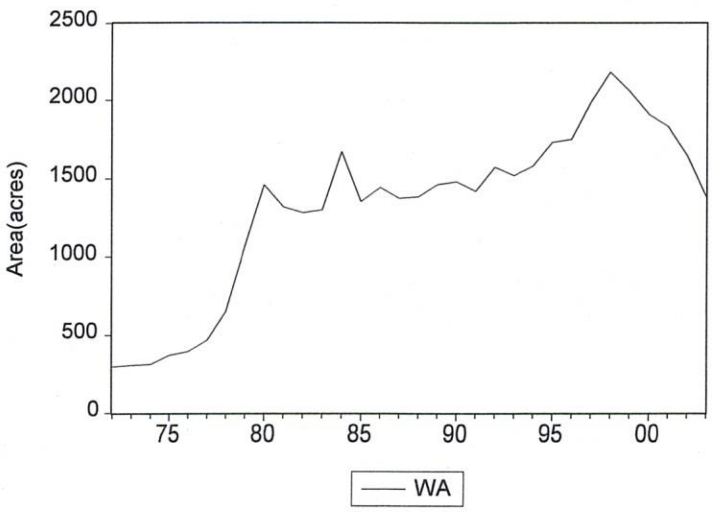


6.6 Data Description of Wheat

6.6.1 Area of Wheat

Area under wheat increases dramatically during the period of 1972-73 to 1980-81 by 43.5 percent. The increase in wheat area practically accounts for all of the increase in intensity of land utilization through multiple cropping over the period 1972-73 to 1980-81 (Rahman, 1986: 69). Area under wheat is declined at the rate of 7.2 percent in the 2000s against an increase of wheat area at the rate of 1.2 percent in the 1980s and 4.3 percent in the 1990s. Growth of area under wheat shows upward trend in Figure 6.16.

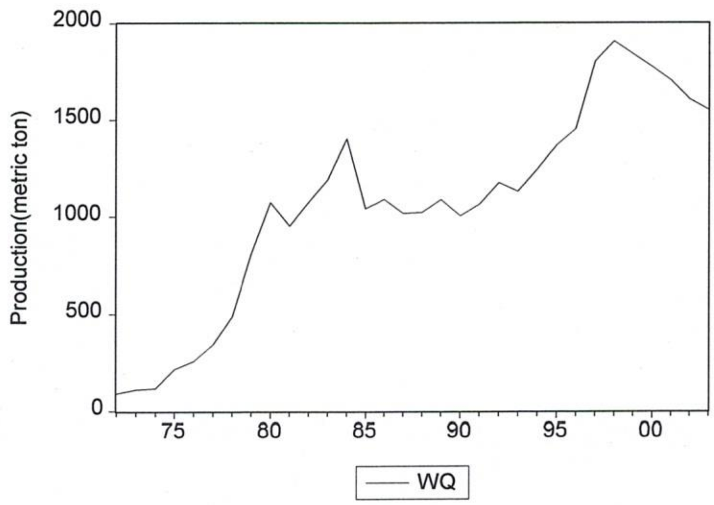
Figure 6.16: Trend of Wheat Area



6.6.2 Wheat Production

Wheat production is increased from 90 metric tonnes in 1972-73 to 1075 metric tonnes in 1980-81 making an annual growth rate over 121 percent. Wheat production begins to reach an impressive level from 1979-80 although its production has reached over 200 thousand tonnes in 1975-76 (Rahman, 86:68). Wheat production is decline in the 2000s (12.4 percent) but experiences high rate of growth (6.75 percent) in the 1990s. Figure 6.17 shows a clear upward trend of wheat production over the period 1972-73 to 2002-03.

Figure 6.17: Trend of Wheat Production



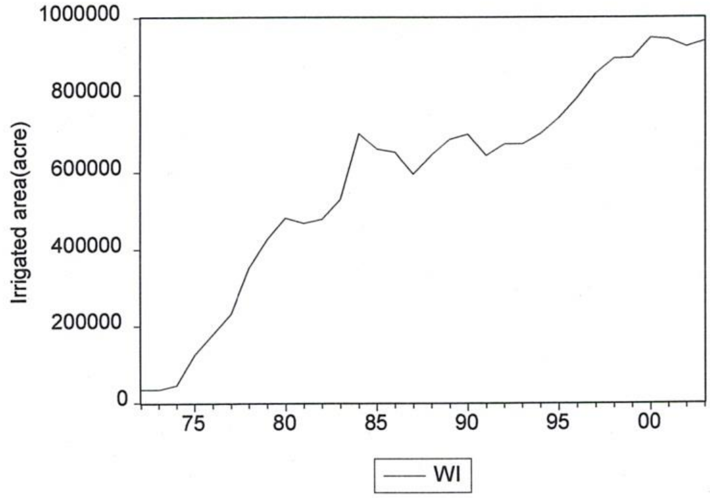
6.6.3 Yield of Wheat

Wheat yield is increased by 16.3 percent during the period of 1972-73 to 1980-81. But average wheat yield at the national level has experienced negative growth (-5.2 percent) in the 2000s, 2.4 percent annual growth in the 1990s, and negative growth (-3.1 percent) in the 1980s.

6.6.4 Irrigated Area of Wheat

Irrigated area under wheat shows sharp upward trend. According to appendix 6.4 and Figure 6.18, irrigated area under wheat is sharply increased after the mid eighties (1972-78). It is seen that area under wheat increased significantly during the period of 1972-73 to 2003-04. It is necessary to mention here that wheat is relatively new food item to the people of Bangladesh and its demand is increasing.

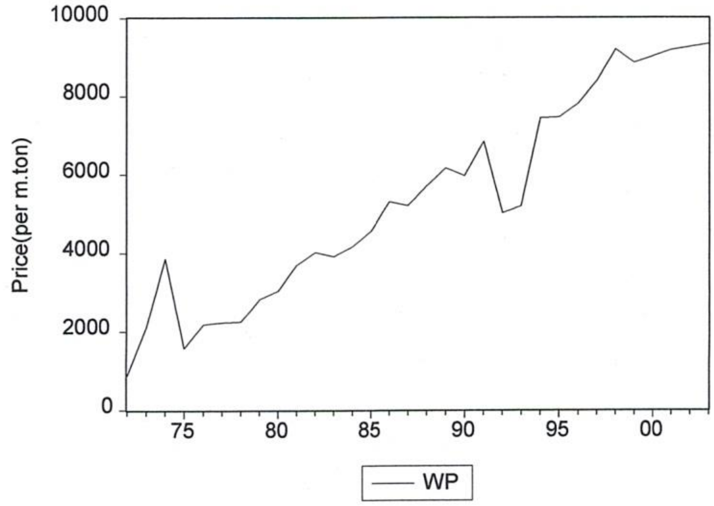
Figure 6.18: Trend of Irrigated Area of Wheat



6.6.5 Price of Wheat

Price of wheat is shown in Figure 6.19 over the period 1972-73 to 2003-04. Wheat price is sharply increased just after immediate period of independence of Bangladesh. It is found that average price level of wheat increases remarkably over the period. This increasing trend is not smooth rather, it is highly fluctuating (Rahman, 1986). This is occurred due to instability of wheat production and (non) availability of food aid to the country.

Figure 6.19: Trend of Wheat Price



6.7 Limitations of the Data

Price and non-price variables are determining factors of crop supply. In addition, some qualitative factors significantly influence crop supply of Bangladesh agriculture. These are discussed in section seven of chapter two. To overcome complexity of model construction and simplicity of analysis, this study considers some selective variables on the basis of past and present literature. We use the aggregate level data of Bangladesh.

Rice and wheat account for over 99 percent of the total cereals. So, other crops are not included either due to non-availability of data or they contribute little to agricultural GDP.

Especially after the privatization (since at the end of 1980s) of agricultural input prices, through irrigation machinery, HYVs, fertilizer, pesticides are the reflection of technical progress of agriculture in a country. We use data for irrigated area as a measure of technological development.

6.8 Conclusions

This chapter provides an elaborate description with graphical presentation of selected variables that have been used for this study.

Both area and production of aus rice are falling over the period 1972-73 to 2003-04. Irrigated area shows downward trends following trends of area and production. But growth rate of yield shows upward trend during the period. It is the indication of technological adoption in crop sector in Bangladesh.

Area of aman is highly fluctuating during period the 1972-73 to 2003-04. It falls dramatically during 1980s. This happens due to adoption of HYVs by farmers through replacing local rice varieties (broad cast aman). Growth on production, irrigated area, yield rate and price variables are moving upward.

Area of boro significantly increases over the period 1972-73 to 2003-04. But production of boro rice and yield rate grows slowly. Area of wheat expands initially but at the end of 1990s it falls. Growth of other variables also shows upward trend.

Appendix 6.1: Aus Rice 1972-2004

Period	Area (acre)	Production (m. ton)	Price (tk.per/m.ton)	Irrigated area (acre)	Yield (kg/ac)
	Aa	*Qa*	*Pa*	*Ia*	*Ya*
1972-73	7240795	2273425	944	107560	313.97
1973-74	7681045	2802035	1242	172300	364.80
1974-75	7856715	2858965	3170	178020	363.89
1975-76	8452365	3230100	2064	182117	382.15
1976-77	7951805	3011435	1547	189660	378.71
1977-78	7814910	3103190	2061	211030	397.09
1978-79	7995270	3287953	1998	228371	411.24
1979-80	7504620	2809345	2187	227040	374.35
1980-81	7686580	3236610	2598	295780	421.07
1981-82	7774000	3270000	3352	279330	420.63
1982-83	7805000	3067000	3535	309615	392.95
1983-84	7756140	3221631	3608	358295	415.37
1984-85	7259765	2782661	4904	347455	383.30
1985-86	7030120	2827220	4431	406600	402.16
1986-87	7175900	3129360	4888	405210	436.09
1987-88	6890670	2993125	5761	293412	434.37
1988-89	6633000	2856000	5568	356970	430.57
1989-90	5593125	2487530	5628	349710	444.75
1990-91	5216360	2328300	5734	339935	446.35
1991-92	4735160	2178520	6337	377710	460.07
1992-93	4287230	2074890	5682	359981	483.97
1993-94	4076410	1850260	4367	319012	453.89
1994-95	4111210	1790670	6183	307496	435.56
1995-96	3810040	1676020	6780	283770	439.90
1996-97	3934720	1870750	5018	276358	475.45
1997-98	3867970	1874730	6416	260000	484.68
1998-99	3519480	1616880	7694	237000	459.41
1999-00	3339250	1733910	7225	238000	519.25
2000-01	3277000	1916000	7420	231000	584.68
2001-02	3069000	1808000	na	na	589.12
2002-03	3073000	1851000	na	na	602.34

Source: Agriculture Statistical Year Book-98
Economic Trend, Bangladesh Bank, 98
Statistical Year Book 1998, 2000
Economic Review 2005

Appendix 6.2: Aman Rice Data 1972-2004

Period	Area	Production	Price	Irrigated area	Yield rate
	('000'acre)	('000'm.ton)	(tk.per/m.ton)	(acre)	(kg/acre)
	Am	*Qm*	*Pm*	*Im*	*Ym*
1972-73	14121	5677	1113	254590	0.402
73-74	14133	6807	1784	294160	0.482
74-75	13469	6096	3750	275250	0.453
75-76	14236	7156	1974	208003	0.503
76-77	14355	7017	1945	208370	0.489
77-78	14261	7541	2247	208045	0.529
78-79	14347	7548	2797	241439	0.526
79-80	14761	7420	3121	317765	0.503
80-81	14918	7963	3069	347030	0.534
81-82	14854	7209	3528	455437	0.485
82-83	14812	7609	3628	480050	0.514
83-84	14845	7936	4369	392480	0.535
84-85	14112	7930	5223	385855	0.562
85-86	14876	8543	4589	469605	0.574
86-87	14958	8267	6002	470105	0.553
87-88	13816	7813	6241	394878	0.566
88-89	12606	6967	6130	522211	0.553
89-90	14095	9004	5553	528355	0.639
90-91	14273	9167	6469	526685	0.642
91-92	14068	9269	6592	584510	0.659
92-93	14442	9680	5119	595789	0.670
93-94	14029	9419	5315	649023	0.671
94-95	13824	8509	7479	793998	0.616
95-96	13953	8790	7665	730334	0.630
96-97	14339	9552	5930	752166	0.666
97-98	14353	8850	7191	837000	0.617
98-99	12762	7736	7929	721000	0.606
99-00	14097	10309	7125	743000	0.731
00-01	14110	11249	7420	381000	0.797
2001-02	14247	11320	7680	684500	0.795
2002-03	14280	11460	7760	745000	0.803
2003-04	14315	11521	7480	850000	0.805

Source: Agriculture Statistical Year Book-98
Economic Trend, Bangladesh Bank 98
Statistical Year Book 1998, 2000
Economic Review 2005

Appendix 6.3: Boro Rice Data 1972-2004

Period	Area ('000'acre)	Production ('000'm.ton)	Price (tk.per/m.ton)	Acre (irrigated area)	Yield rate (kg/acre)
	Ab	*Qb*	*Pb*	*Ib*	*Yb*
1972-73	2434	2104	1178	2220860	0.864
73-74	2595	2256	1716	2361900	0.869
74-75	2871	2286	3012	2699650	0.796
75-76	2837	2323	1922	2618126	0.819
76-77	2112	1676	1842	2022925	0.794
77-78	2703	2275	1977	2575285	0.842
78-79	2649	1960	2927	2436490	0.740
79-80	2839	2466	2987	2491750	0.869
80-81	2867	2630	2900	2467500	0.917
81-82	3542	3460	3390	2574043	0.977
82-83	3342	3446	3608	2816785	1.031
83-84	3463	3350	4359	2959685	0.967
84-85	3891	3909	4042	3175860	1.005
85-86	3789	3671	4457	3110760	0.969
86-87	4082	4010	5340	3368235	0.982
87-88	4800	4807	4844	4146396	1.001
88-89	6026	5925	5608	4608891	0.983
89-90	6205	6167	5512	5066220	0.994
90-91	6297	6357	6155	5257805	1.010
91-92	6512	6804	6225	5720510	1.045
92-93	6423	6587	4387	5733932	1.026
93-94	6378	6772	4918	5740850	1.062
94-95	6582	6538	6541	5910398	0.993
95-96	6804	7221	5664	6251916	1.061
96-97	6876	7460	5898	6430021	1.085
97-98	7138	8137	7414	6624000	1.140
98-99	8715	10552	7709	7086000	1.211
99-00	9024	11027	7078	7506000	1.222
00-01	9295	11920	7650	7900000	1.282
2001-02	9452	14253	7825	8145000	1.508
2002-03	9548	16520	7925	8345000	1.730
2003-04	9760	16954	8230	8540000	1.737

Source: Agriculture Statistical Year Book-98
Economic Trend, Bangladesh Bank 98
Statistical Year Book 1998, 2000
Economic Review 2005

Appendix 6.4: Wheat Data 1972-2004

Period	Area ('000'acre)	Production ('000'm.ton)	Price (tk.per/m.ton)	Acre (irrigated area)	Yield rate (kg/acre)
	Aw	*Qw*	*Pw*	*Iw*	*Yw*
1972-73	297	90	874	34250	0.303
73-74	305	109	2113	34050	0.357
74-75	311	115	3866	45442	0.370
75-76	371	215	1571	125102	0.503
76-77	395	255	2183	178620	0.646
77-78	467	343	2233	231805	0.734
78-79	654	486	2252	351927	0.743
79-80	1071	810	2828	426225	0.756
80-81	1461	1075	3048	481320	0.736
81-82	1320	952	3702	468478	0.721
82-83	1283	1078	4018	478225	0.840
83-84	1300	1192	3914	529915	0.917
84-85	1371	1403	4162	699950	0.840
85-86	1355	1043	4552	659685	0.781
86-87	1445	1091	5302	651350	0.755
87-88	1476	1018	5201	485031	0.690
88-89	1384	1022	5708	643792	0.738
89-90	1463	890	6160	685415	0.608
90-91	1480	1004	5963	697965	0.978
91-92	1420	1065	6844	642680	0.750
92-93	1574	1176	5009	672746	0.747
93-94	1520	1131	5186	672524	0.744
94-95	1580	1245	7444	699372	0.788
95-96	1732	1369	7463	741168	0.790
96-97	1749	1454	7309	791796	0.831
97-98	1988	1803	8391	854019	0.907
98-99	2180	1908	9200	894000	0.875
99-00	2057	1840	8860	896000	0.895
00-01	1909	1673	8920	948000	0.876
2001-02	1885	1720	9040	965400	0.876
2002-03	1825	1750	9100	975420	0.863
2003-04	1860	1865	9280	987600	0.790

Source: Agriculture Statistical Year Book-98
Economic Trend, Bangladesh Bank 98
Statistical Year Book 1998, 2000
Economic Review 2005

Chapter 7
Unit Root Results

7.1 Introduction

The present or absence of unit root is of importance in empirical models based on time series data, where price and non-price related variables are significant explanatory variables, when models examine relationship between these variables and supply response in agriculture. The data generating process of agriculture supply response has been assumed to be stationary (absence of a unit root) in almost all the earlier studies in Bangladesh. However, in cases this assumption is not valid, standard asymptotic distribution theory can not be used for the purpose of drawing inference. Because traditional regression analysis in models that is include variables with unit root can produce Spurious" or "crazy" regression result (Granger and Newbold 1986).

Although, it has become almost necessary to pre-test for the presence of unit root in applied econometric works, this by no means is a simple exercise. Practically most econometric time series data shows trends and are non-stationary (Nelson and Plosser, 1982; Perron, 1988). Any time series has a unit root where its first difference is stationary. Therefore, as first step in any time series empirical analysis is to test for the presence of unit roots in order to remove the problem of spurious regression. In this stage it is needed to explore the order of each variable to establish whether it contains unit roots and how many times it needs to be differenced to draw a stationary series.

In this study acreage, yield price and irrigated area of rice and what are tested for unit roots for the period (1972-73 to 2003-04). Three types of rice and wheat data are available after independence of Bangladesh. Irrigated area variable is employed to represent technological change. Irrigated area is specifically thought to be the best supply shifters in the acreage equation.[14]

The chapter is organized as follows, section 7.2 represents a graphical analysis of data series to examine whether a unit root exist in each series. Section 7.3 produces the results for testing the null hypothesis of a unit root against the alternative of stationarity using the Augmented Dickey–Fuller test. Section 7.4 stats a summary and conclusions of this chapter.

7.2 Graphical Presentations

As first step to test the unit root of time series data, it is needed to observe graphical presentations of each series. Because it is convenient to detect qualitative feature such as trends and structural breaks. The Graphs of each series in levels and first differences are presented in Appendix 7 at the end of this chapter.

It is observed from graphical presentation that area of aus (Aa), production of aus $InQa$, price of aus (Pa), yield of aus (Ya), the aman price (Pm), production of aman (Qm), yield of aman (Ym), area of boro (Ab), price of boro (Pb), production of boro (Qb), yield of boro (Yb), wheat area (Aw), wheat price (Pw), production of wheat (Qw), irrigated area under wheat (Iw), yield of wheat (Yw) show linear trends . But area of aman (Am) and irrigated area under aus (Ia), do not show any clear trend. We apply econometric procedure for examining presence of unit roots which are discussed in chapter five (econometric methodology).

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[14] Parikh and Triverdi (1979) and Bardhan (1973) assumes that output elasticity in relation to irrigated acreage is treated as a measure of the contribution of technological progress to output.

7.3 Testing for Unit Roots

Before specifying the respective crop supply equations, the order of integration of the time of the variables, and the existence of cointegration between them need to be determined. We test for unit root test of twenty variables of four crops (aus , aman, boro rice and wheat) which are given in table 6.1. All variables are in logarithmic form.

Tests for unit roots are performed using the ADF tests. Akaike's Information Criterion is used to determine the optimal lag length for the augmented terms. The ADF tests for unit root are applied to check stationary property of the variables. The ADF test results for the logarithms of levels and first differences of all variables (area, production, price irrigated area and yield) are presented in table: 7.1, 7.2, 7.3, and 7.4.

Table 7.1: Aus Rice ADF Test

Variables	Levels	Difference
InAa	0.649	-2.69*
InQa	-0.459	-4.14
InPa	-2.437	-10.343
InIa	-2.255	-4.336
InYa	-0.03	-5.49

Note: The ADF tests reported here are estimation with intercept. If the computed absolute value of the statistics (Dickey-Fuller statistics) is less than the absolute critical values, the time series is considered non-stationary. The 1% Critical Value for Level -.366, 5% CV -2.96 and 10% CV -2.62. The 1% Critical Value for Difference -3.69, 5% CV -2.97 and 10/% CV -2.62

Results of the unit root test of aus rice variables are presented in Table 7.1. The results show that for all variables (*InAa*, *InQa*, *InPa*, *InIa* and *InYa*) the null hypothesis of unit root are not rejected at 5 percent level. On the other hand, when the first differences are tested, the null hypothesis (non-stationarity) are rejected at 5 percent level and variable area of aus (*InAa*) is rejected at 10 percent level. Thus these variables are integrated of order one *I(1)*

Table 7.2: Aman Rice ADF Test

Variables	Levels	Difference
InAm	-0.04	-6.96
*In*Im	0.177	-2.47
InPm	1.49	-6.47
InQm	1.36	-5.08
InYm	-2.00*	-3.88

Note: The ADF tests reported here are without trend and intercept. The 1% Critical Value for Level -2.64, 5% CV -1.95 and 10% CV -1.62. The 1% Critical Value for Difference -2.65, 5% CV -1.95 and 10/% CV -1.62

Results of the unit root test (aman rice variables) are presented in Table 7.2. Result of unit root test show that for all variables area of aman (*InAm*), irrigated area of aman (*In*Im), price of aman (*InPm*) and production of aman (*InQm*) except yield of aman (*InYm*) the null hypotheses of unit root cannot be rejected at 5 percent level and yield of aman (*InYm*) rejected at 10 percent level. But when first differences are tested the null hypothesis (non-stationarity) are rejected. This means that the variables are non-stationary and they are integrated of order one *I(1)*.

Table 7.3: Boro Rice ADF test

Variables	Levels	Difference
InAb	-0.284	-4.27
InIb	0.228	-4.298
InPb	-1.77	-8.41
InQb	0.187	-3.32
InYb	0.247	-3.75

Note: The ADF tests reported here are with intercept. The 1% Critical Value for Level -3.66, 5% CV -2.96 and 10% CV -2.62. The 1% Critical Value for Difference -3.66, 5% CV -2.96 and 10/% CV -2.62

Results of the unit root test of *InAb*, *InPb*, *InIb*, *InQb*, and *InYb* are presented in Table 7.3. Results show that for all variables the null hypothesis of unit root are not rejected at 5 percent level. On the other hand, when the first differences are tested, the null hypothesis (non-stationarity) is rejected. Results of unit root tests indicate that area of boro rice (*InAb*), price of boro (*InPb*), irrigated area of boro (*InIb*), production of boro (*InQb*), and yield of boro (*InYb*) variables and they all have unit root *I(1)*.

Therefore, results confirm that *InAb*, *InPb*, *InIb*, *InQb*, and *InYb* variables are integrated of order one in levels but integrated of order zero in first differences.

Table 7.4: Unit Root Test Results of Wheat ADF Test

Variables	Level	Difference
InAw	0.976	-2.46
InQw	0.925	-1.8
InPw	1.237	-10.5
InIw	1.217	-4.8
*InYw**	-3.55	-2.99

Note: The ADF tests reported here are without trend and intercept. The 1% Critical Value for Level -2.64, 5% CV -1.95 and 10% CV -1.62. The 1% Critical Value for Difference -2.65, 5% CV -1.95 and 10/% CV -1.62

Results of the unit root test of *InAw*, *InQw*, *InPw* and *InIw* are presented in Table 7.4. The table 7.4 show that for all variables except yield of wheat *InYw*, the null hypotheses of unit root are not rejected at 5 percent level. On the other hand, when the first differences are tested, the null hypotheses (non-stationarity) are rejected. Results of unit root tests indicate that wheat area *InAw*, production of wheat *InQw*, price of wheat *InPw*, and irrigated area of wheat *InIw* are non-stationary variables and they all have unit root *(1)*. The rest of the one variable yield of wheat *InIw* are said to be *I (1)*.

Therefore, results confirm that, *InAw*, *InQw*, *InPw* and *InIw* variables are integrated of order one in levels but integrated of order zero in first differences.

7.4 Conclusions

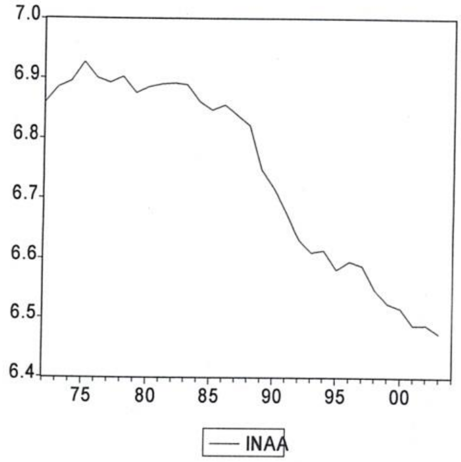
For time series analysis it is needed to check variables whether they are stationary or not to avoid spurious regression results. On the basis of our methodologies which are discuses in chapter 5, we carry out the ADF test results indicate unit roots in level. We then take first difference of variable and find that they are stationary.

All variables are *I(1)* except for yield of wheat (I_W). All variables are integrated of *order 1* in levels but integrated of order *zero* in first differences.

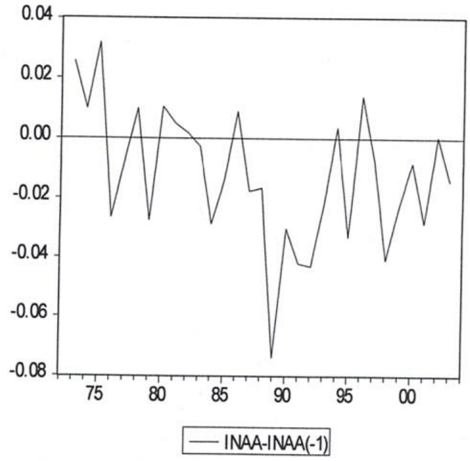
Appendix 7.1 Levels and First Differences of Area, Price, Production, Irrigated Area and Yield

Area of Aus *(Aa)*

Level

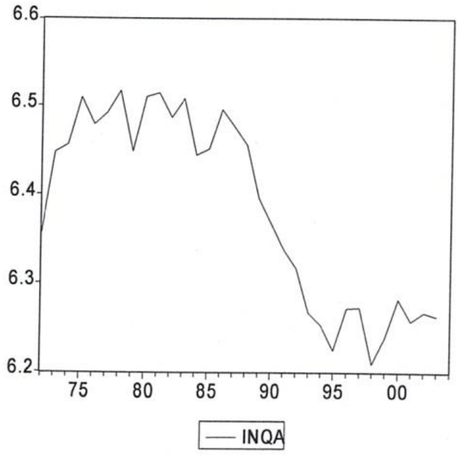


First difference

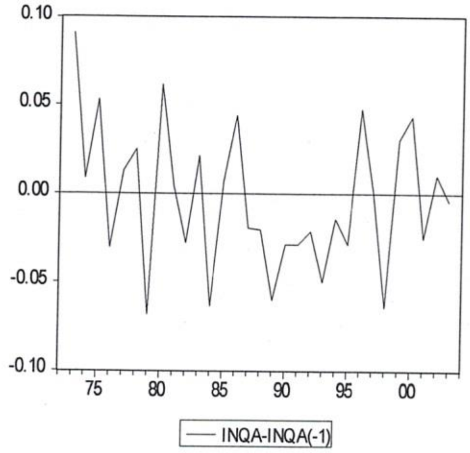


Production of Aus *(Qa)*

Level

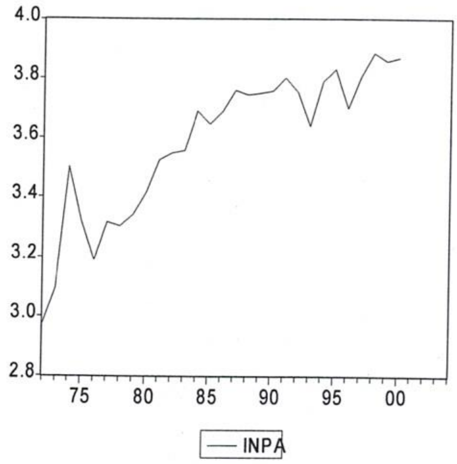


First difference

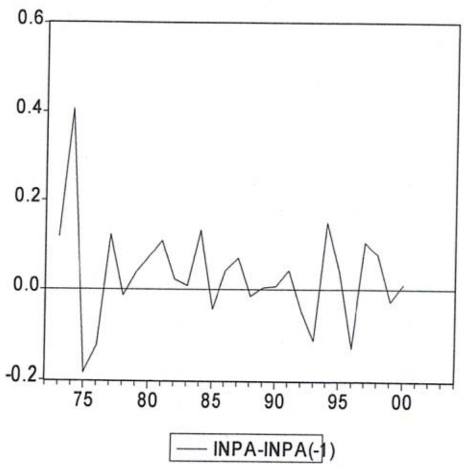


Price of aus *(Pa)*

Level

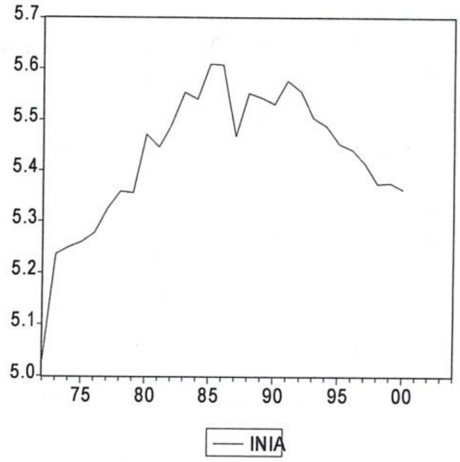


First difference

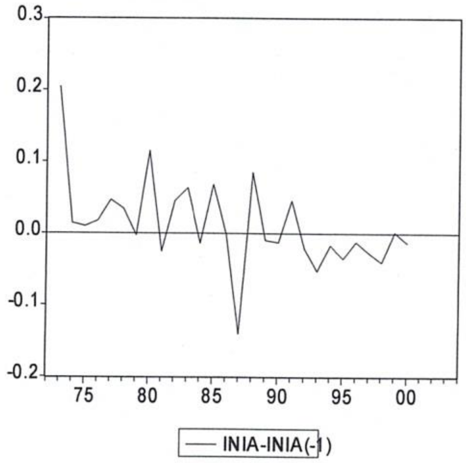


Irrigated area under aus rice *(Ia)*

Level

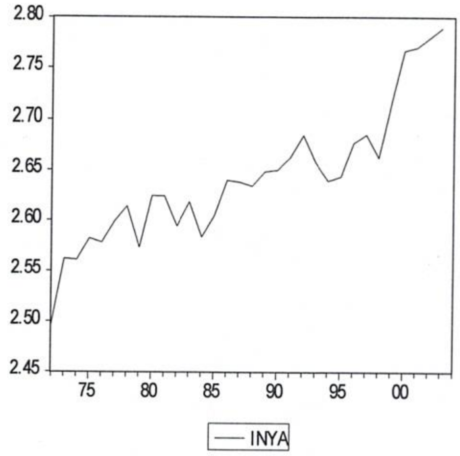


First difference

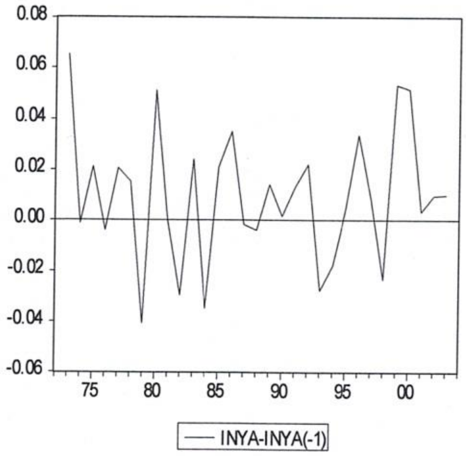


Yield of aus rice *(Ya)*

Level

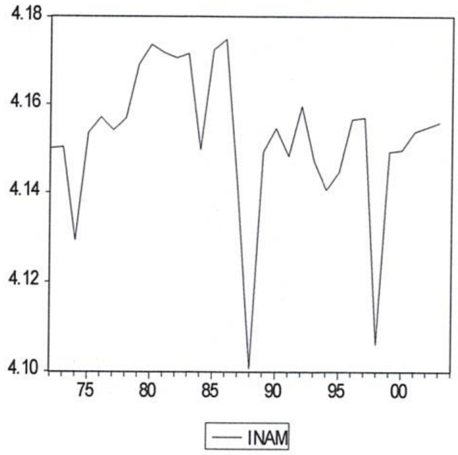


First difference

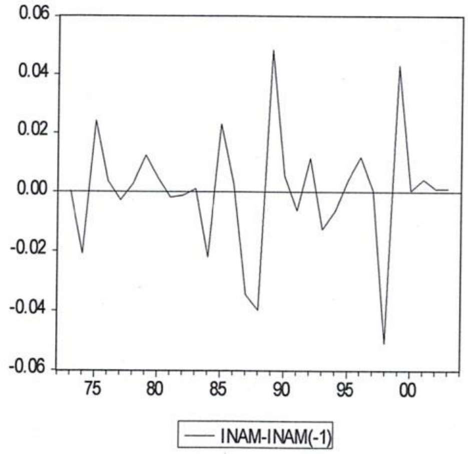


Area of aman rice *(Am)*

Level

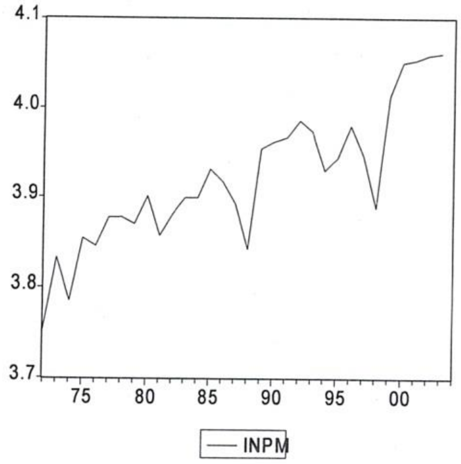


First difference



Price of aman (P_m)

Level



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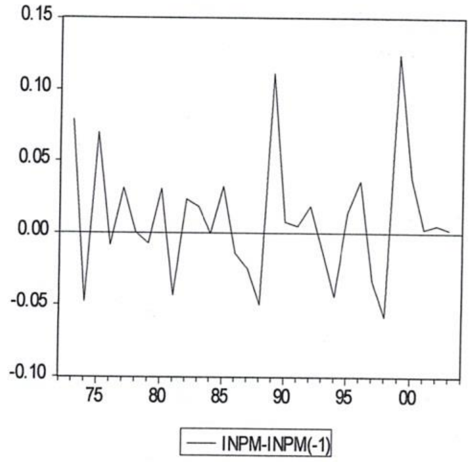
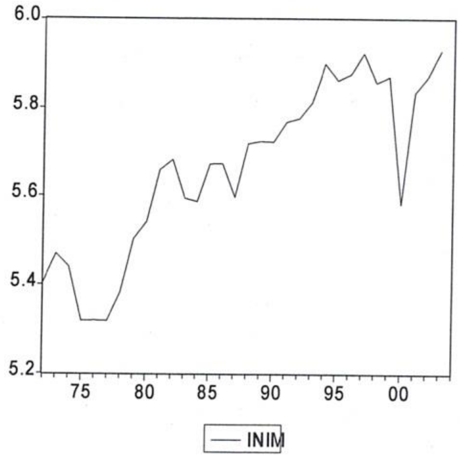


Irrigated area under aman rice *(Im)*

Level



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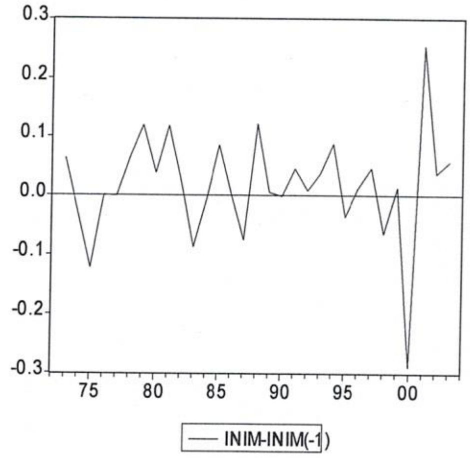
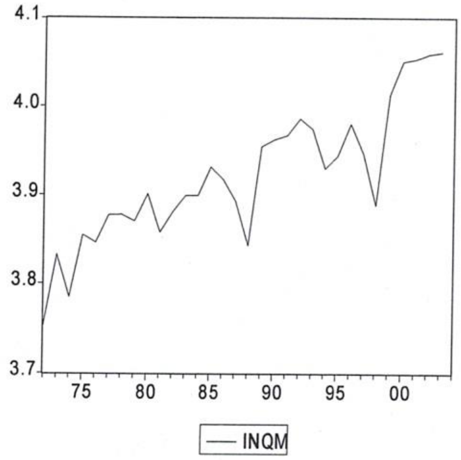


Production of aman rice *(Qm)*

Level



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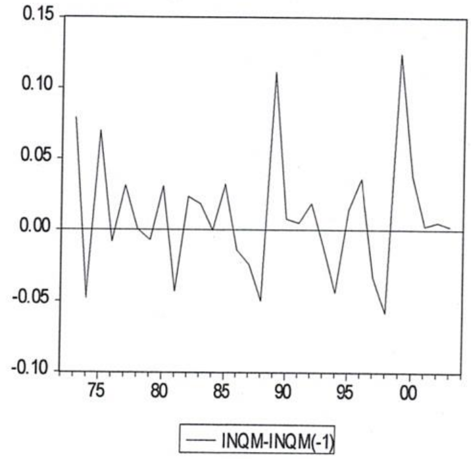
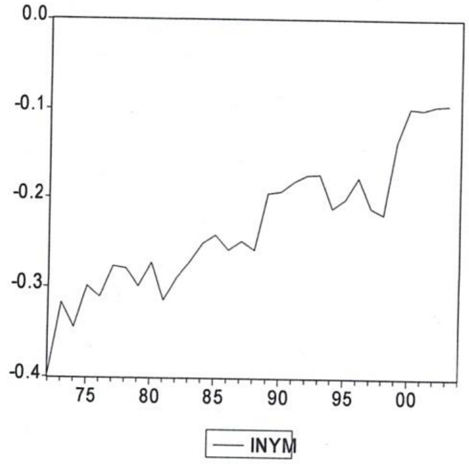


Yield of aman rice *(Ym)*

Level



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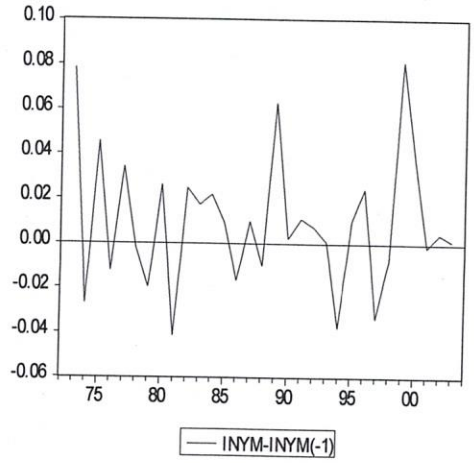
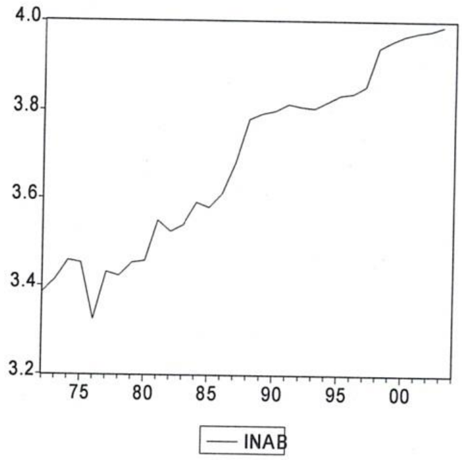


Area of boro rice *(A_b)*

Level



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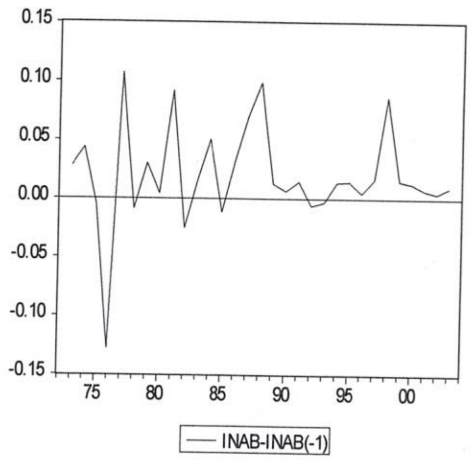
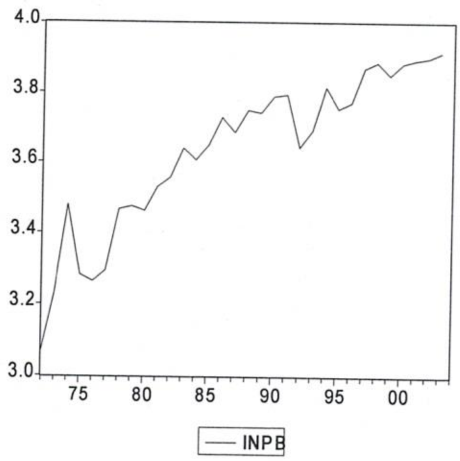


Price of boro rice *(P_b)*

Level



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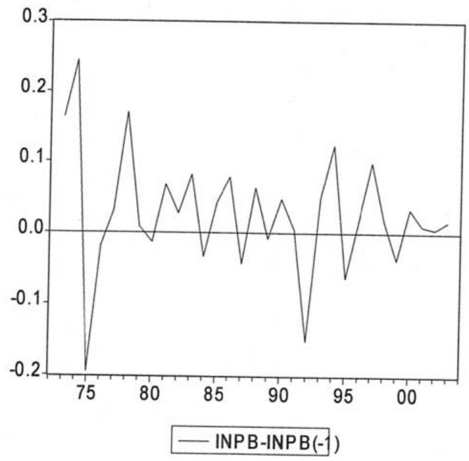
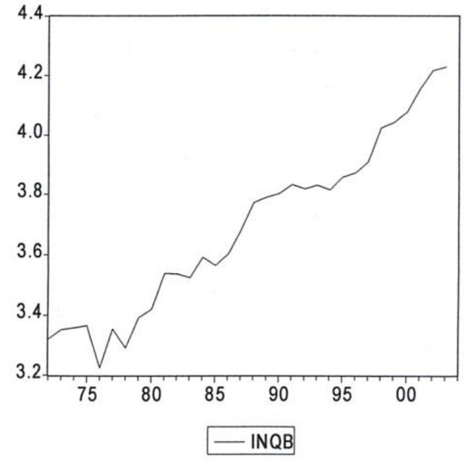


Production of boro rice (Q_b)

Level



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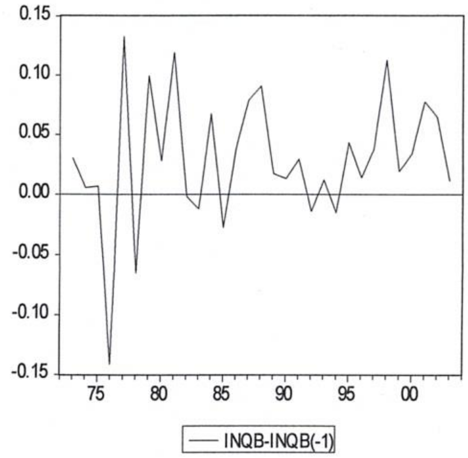
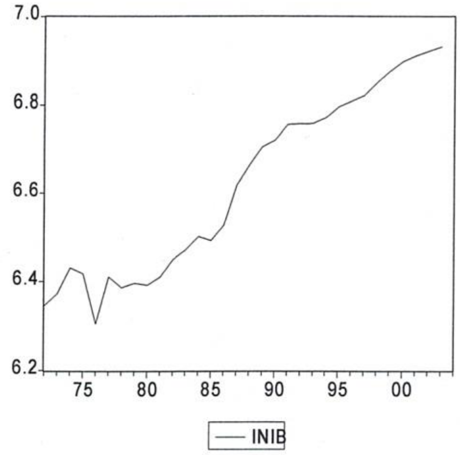


Irrigated area under boro rice (I_b)

Level



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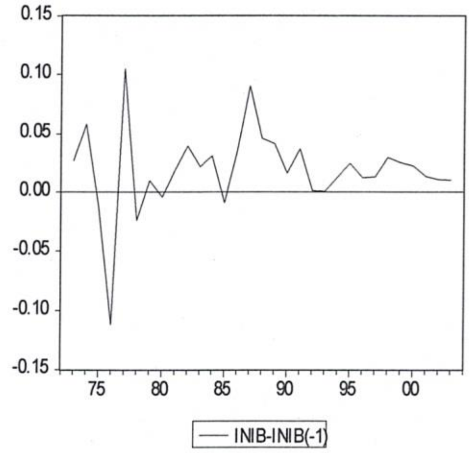
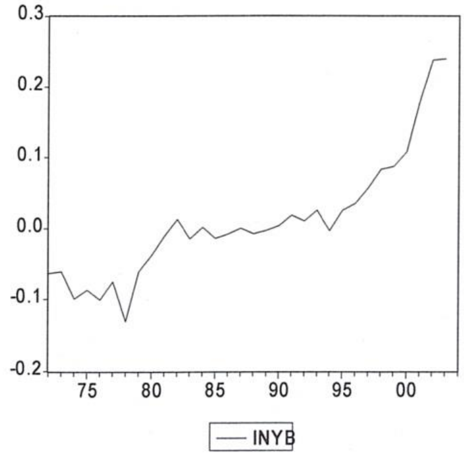


Yield of boro rice (Y_b)

Level



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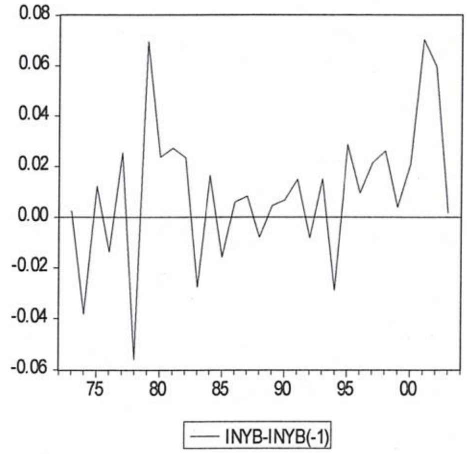
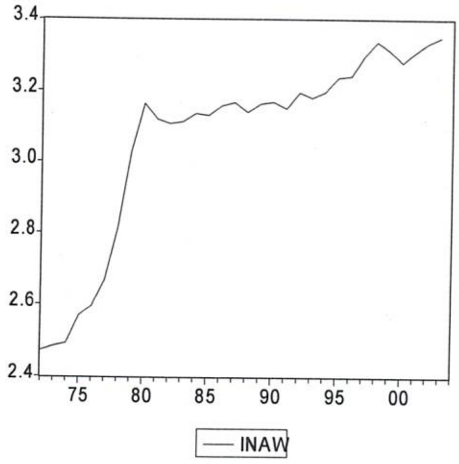


Wheat Area *(Aw)*

Level



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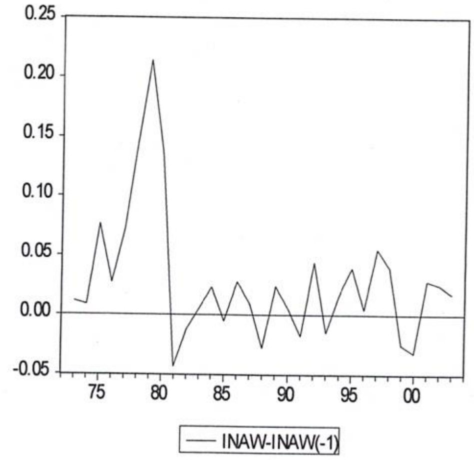
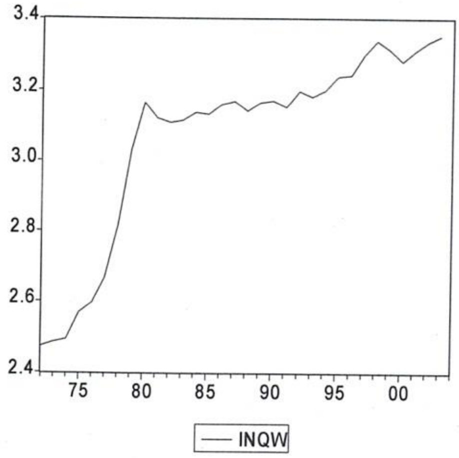


Wheat production *(Qw)*

Level



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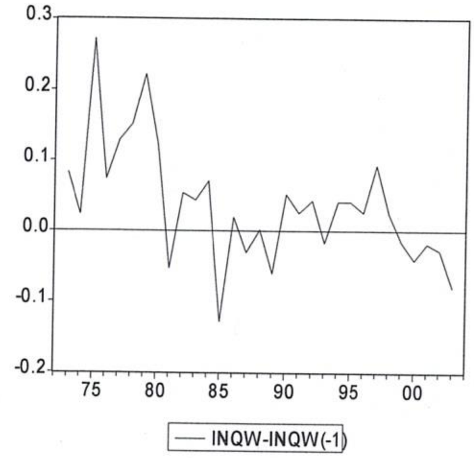
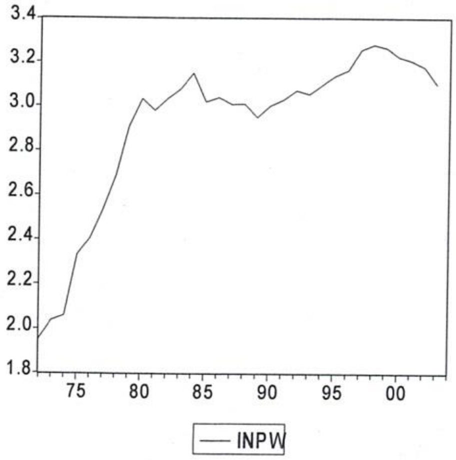


Price of Wheat *(Pw)*

Level



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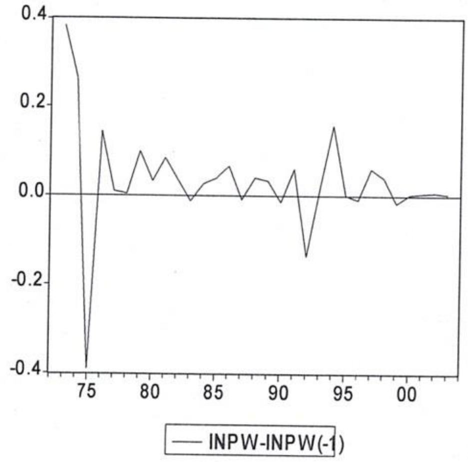
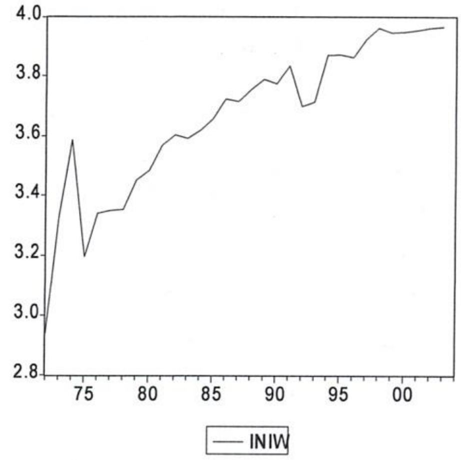


Irrigated area under wheat *(Iw)*

Level



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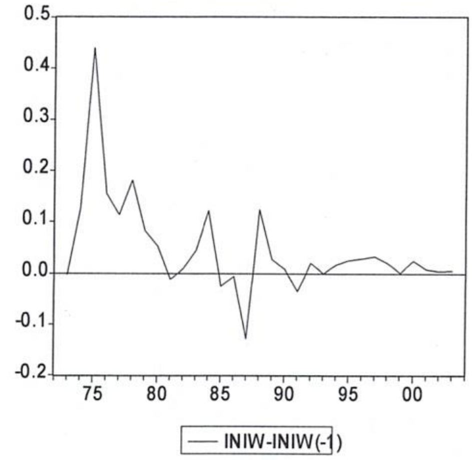
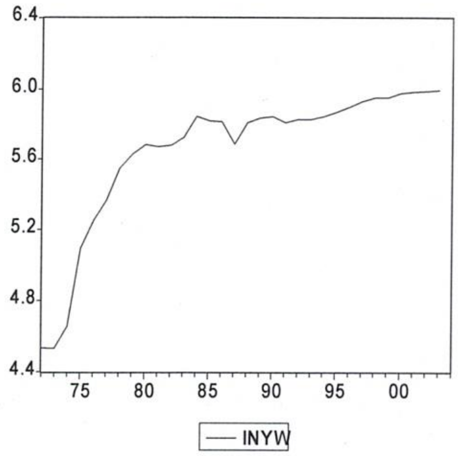


Yield of wheat *(Yw)*

Level



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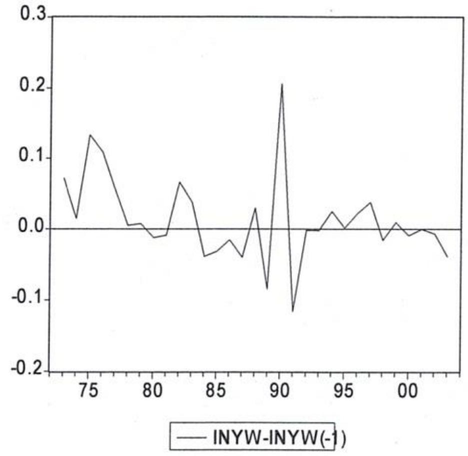

Chapter 8
Cointegration and ECM Results

8.1 Introduction

Empirical procedures are carried out in the following steps. First, annual data from 1972-73 to 2003-04 are obtained for five time series are subjected to a set of unit root tests. After checking unit root tests to confirm that each series is a *I(1)* processes, Johansen Maximum Likelihood procedures are used to test for cointegration and to estimate Error correction parameters.

The long term effects of the variables can be represented by the estimated cointegration vector; however, the impulse response functions have to be relied on to reveale the short term dynamics between these variables can be plotted with the estimated coefficient matrices and the error variance matrix. This study in particularly interested in the long term effect of price, output, irrigation, yield rate on acreage decision, and the short term dynamics towards the steady state after an exogenous shock to price, output, irrigation and yield rate. In summary, the estimated cointegration vector will answer the question of the long-run relations.

8.2 Supply Response for Aus Rice

The aus acreage (A_a) is estimated to be a function of its own price (P_a), production (q_a), irrigated area (I_a) and yield rate (Y_a). Thus we write

$$A_a = f\ (P_a, Q_a, I_a, Y_a)$$

This study applied Johansen's procedure to the rice acreage models. The first step of the Johansen procedure is the selection of the order of the VAR by using the following equation, which is already produced in the methodological section of chapter five.

$$Z_t = A_1 Z_{t-1} + ... + A_k Z_{t-k} + u_t \qquad (8.1)$$

8.2.1 Identification of Cointegration Vectors and Estimation of the Model

Following the steps of the Johansen procedure, hypothesis testing procedures were carried out to select the order of VAR, starting with a maximum lag length of four. A lag length of more than four is not considered because of the limited sample size. If the residuals do not suffer from serial correlation, it is appropriate to select a lower lag length although incorporating additional coefficients will reduce the degree of freedom. Results from the lag length test suggest that possible lag lengths lie between one and four. Although a shorter lag length is preferred, there is no practical basis for considering order one for error correction model, because to do so would directly imply that there is no short-run dynamic part in the model after fixing the long-run behaviour. Thus the analysis is restricted to order two. The rank of the cointegration, i.e., the number of cointegrating vectors, is selected by using the maximum eigen value test.

The second step in the Johansen procedure is to test for the presence and number of cointegrating vectors among the series in the model. Results are presented in Table 8.1. This study use the 5 percent significance level except where stated.

Table 8.1: Results of Johansen's Cointegration Test

Cointegration rank	Eigen value	Likelihood ratio	5 % Critical value	Decision
$r = 0$	0.65	68.24	59.46	none
$r \leq 1$	0.47	37.10	39.89	At most 1

Note: L. R. test indicates cointegrating equation(s) at 5 percent significance level.

Results show that since the LR value is greater than the critical is rejected. The hypotheses of one cointegrating vector are accepted. The Johansen cointegration result in Table 8.1 indicates that aus acreage (A_a) model (without dummies) has one cointegrating vector. It is also means unique long-run equilibrium relationship among the variables.

The Johansen model is a form of ECM and where exits only one cointegrating vector its parameters can be interpreted as estimates of the long-run cointegrating relationship between variables (Hallam and Zanoli, 1993). Following the estimated parameter values from these equations when normalised on acreage is the long-run elasticities. The coefficient expresses estimates of long-run elasticities of aus acreage with respect to price, output, irrigated area and yield.

If, cointegration is established among the variables, there is an error correction mechanism (ECM). The dynamic ECM framework is an ideal basis for supply response analysis because it provides information about the speed of adjustment to long-run equilibrium and avoids the spurious regression problem between the variables (Engle and Granger, 1987).The ECM for acreage is:

$$\Delta A = \delta_0 + \sum_{i=1}^{4} \delta_{1i} \Delta A_{t-1} + \sum_{i=1}^{4} \delta_{2i} \Delta P_{t-1} + \sum_{i=1}^{4} \delta_{3i} \Delta Q_{t-1} + \sum_{i=1}^{4} \delta_{4i} \Delta I_{t-1} + \sum_{i=1}^{4} \delta_{5i} \Delta Y_{t-1} - \alpha EC_{t-1}$$

Where $-\alpha EC_{t-1} = \alpha(A_{t-1} - \beta_1 P_{t-1} - \beta_2 Q_{t-1} - \beta_3 I_{t-1} - \beta_4 Y_{t-1})$

The Long-run cointegrating vectors (adopted from aus cointegration equation) are demonstrated in Table 8.2.

Table 8.2: Long-term Cointegration Vectors (price vector with short-run coefficient)

Acreage	Prices		Irrigated area (long-run)	Production (long-run)	Yield (long-run)	Adjustment coefficient of acreage
	Short-run	Long-run				
Aus	0.12 (1.5)	0.98 (2.65)	1.09 (-2.67)	0.28^{NS} (0.67)	0.95 (-1.73)	0.12 (-1.55)

Note: NS-Non significance, Figures in Parentheses show the value of t-statistics

Orders of the variables of price of aus (P_a), irrigated area (I_a), production (Q_a) yield rate (Y_a) are displayed in Table 8.2. The coefficient of price is of major interest. This is 0.98, which is unitary elastic and significant at 1 percent level. This implies that a 1 percent increase in aus price, aus area (A_a) at the aggregate or national level will increase by 0.98 percent in the long-run. The short-run acreage elasticity of aus is 0.12 which is in inelastic range and significant at 10 percent level. It means that 1 percent increase in aus price; aus area at national level will increase by 0.12 percent in the short-run.

Other variables also affect aus area. Irrigated area has positive impact on aus area distribution. The estimated coefficient for irrigated area is 1.09 at 1 percent significant level. Yield rate of aus also positively affect cultivated area of aus with elasticity of 0.95 at 10 percent significant level.

Results suggest that supply of aus is responsive to its own price. In that case price support policy is effective at the same way irrigation schemes has a positive impact on supply of aus rice. In response to policy options government should takes measure to extent irrigation infrastructure.

The normalization of the cointegrating vector depends on the variables in question; this means that any selected variable can be normalized. In terms of vector five it is irrelevant which variable on the left hand is shown to be one. It should be noted that vector five simply describes a long term relations among the included variables, but does not necessarily imply causality among variables, because VAR is consistent with idea of dual effects between or among the variables.

The cointegration equation of aus also gives the long term adjustment coefficients, this shown the extent to which the current change in vector Z is a response to the last time deviation to converge with the long-term relation. In other words, the Figures in this row identify the fraction of the long gap that is closed in each period. The equation of the aus area (A_a), shows that the remaining long-term area of aus area (A_a) adjusts by about 12 percent in each period. In other words the adjustment coefficient is (0.12), which inferred that 12 percent of adjustment in aus area caused by the fluctuation of exogenous variables takes place in a year. The remaining adjustment shock will be made in subsequent years.

The other coefficients from the aus cointegration equations are short-run dynamics. These parameters control the short-run dynamics of the changes in vector Z of equation 8.1. The short-run dynamics describe how current changes are related to previous changes in vector Z. Because the algebraic representations of these lag difference responses is complex. It is common practice to show them as impulse functions, which can demonstrate the short term changes in vector *Z*. Note that all short term changes in vector *Z* are combined results of short term responses from the auto regression (AR) term and long term cointegration relations.

8.3 Supply Response for Aman Rice

The aman model is estimated without structural break and dummies. Aman acreage (A_m) is assumed to be a function of its own price (P_m) production (Q_m), and irrigated area (I_m) .This is written as:

$$A_m = f\ (P_m, Q_m, I_m)$$

Results of cointegration tests have been included in Table 8.3.

Table 8.3: Results of Johansen's Cointegration Test

Cointegration rank	Eigen value	Likelihood ratio	5% Critical value	Decision
$r = 0$	0.55	52.01	47.21	None*
$r \leq 1$	0.50	27.93	29.68	At most 1

Note: L.R. test indicates cointegrating equation(s) at 5percent significance level

Since the LR value from Table 8.3 is greater than the critical value at 5 percent significance level, the null hypotheses of no cointegration are rejected. The hypothesis of one cointegrating vector is accepted. The Johansen cointegration results in Table 8.3 indicate that the aman rice acreage model has one cointegrating vector. It also means unique long-run equilibrium relationship among the variables.

We signify long-term cointegrating vectors of price, irrigated area, and production through following Table 8.4.

Table 8.4: Long-run Cointegration Vectors (Price vector with short-run coefficient)

Acreage	Prices		Irrigated area (long-run)	Production (long-run)	Adjustment coefficient of acreage
	Short-run	Long-run			
Aman	0.06 (1.58)	0.31 (2.33)	0.34 -2.24	0.14^{NS} (0.86)	0.27 (-1.7)

Note: NS-Non significance, Figures in Parentheses show the value of t-statistics

According to Table 8.4, the long-run coefficient of aman price (P_m) is 0.31, which is significant at 5 percent level. This expresses that a 1 percent increase in price level will increase aman area at the aggregate or national level by 0.31 percent in the long-run. Irrigated area also positively affects aman acreage (A_m) with elasticity of 0.34 at 5 percent significant level. It tells us that 1 percent increase in irrigated area; aman area will increase by 0.34 percent. Our results provide that the short-run aman acreage elasticity to own price is 0.06 this is significant at 10 percent level. It also means that 1 percent increase in aman price lead to increase aman area at 0.06 percent.

Supply of aman rice is not responsive to its own price. In this case input price support policy applicable for increasing aman production.

The cointegration equation of aman rice expresses the long term adjustment coefficients. The equation of the aman area (A_m) shows that the remaining long term area of aman (A_m) adjust about 27 percent in each period. This result implies that area takes comparatively shorter to achieve equilibrium after shock.

8.4 Supply Response for Boro Rice

Boro acreage (A_b) would be a function of own price (P_b), production (Q_b), irrigated area (I_b) and yield rate (Y_b). We can write the function as:

$$A_b = (P_b, Q_b, I_b, Y_b)$$

Results of the cointegration test are displayed in Table 8.5.

Table 8.5: Results of Johansen's Cointegration Test

Cointegration rank	Eigen value	Likelihood ratio	5% Critical value	Decision
$r = 0$	0.70	80.59	65.52	none**
$r \leq 1$	0.55	43.88	47.21	At most 1

Note: L.R. test indicates cointegrating equation(s) at 5 percent significance level.

According to table 8.5 LR value is greater than critical value at 5 percent significance level this implies that the null hypotheses of no cointegration are rejected. The hypothesis of one cointegrating vector is accepted.

The Johansen cointegration results from Table 8.5 indicate that the boro acreage model has one cointegrating vector. It also means unique long-run equilibrium relationship exists between the variables.

Table 8.6 illustrates long-run cointegrating vector of price, irrigated area and production. It also shows adjustment coefficient of acreage.

Table 8.6: Long-run Cointegrating Vectors (price vector with short-run coefficient)

Acreage	Prices		Irrigated area (Long-run)	Production (Long-run)	Adjustment coefficient of acreage
	Short-run	Long-run			
Boro	0.21 (-2.3)	0.95 (-1.5)	0.002^{NS} (-0.0014)	0.7 (-2.0)	0.37 (-4.06)

Note: NS-Non significance, Figures in Parentheses show the value of t-statistics

Table 8.6 shows the long-run coefficient of price (P_b) is 0.95, which is insignificant at 10 percent level. This implies that a 1 percent increase in price increases boro area (A_b) increase at aggregate or national level by 0.95 percent in the long-run. Production or output variable (Q_b) has an impact on area distribution of boro rice. The estimated coefficient for output is 0.7 at 5 percent significant level. Our results also provide that the short-run acreage elasticity of boro to own price is 0.21 which is significant at 5 percent level. This indicates that 1 percent increase in aus price lead to increase aus area by 0.21 percent.

Results tell us that supply of boro rice is responsive to its own price in the long-run. Price support policy is more appropriate for increasing boro production at national level. Various types of price support policy are being used to insist farmers to allocate more area for that particular crop. It depends on degree of responsiveness of particular crop supply to its own price, prices of related product and demand for that crop.

The cointegration of boro equation specifies the long term adjustment coefficients. This shows the extent to which the current change in vector Z is a response to the last time deviation to converge with the long term relation. In other words, the Figures in this row identify the fraction of the long gap that is adjusted in each period. The equation of boro area (A_b) equation shows that the long-term area of boro (A_b) gap adjust by about 37 percent in each period and that is highly significant. These results imply that area take short period to achieve equilibrium after shock.

8.5 Supply Response of Wheat

The wheat acreage (A_w) is estimated to be a function of its own price, (P_w) production (Q_w), irrigated area (I_w) and yield rate (Y_w). This is follows as:

$$A_w = f(P_w, Q_w, I_w, Y_w)$$

Results of the cointegration test are presented in Table 8.7.

Table 8.7: Results of Johansen's Cointegration Test

Cointegration rank	Eigen value	Likelihood ratio	5% Critical value	Decision
$r = 0$	0.77	82.89	59.46	none**
$r \leq 1$	0.54	38.03	39.89	At most 1

Note: L.R. test indicates cointegrating equation(s) at 5 percent significance level.

Table 8.7 expresses that LR value is greater than critical value at 5 percent significance level. This implies that the null hypotheses of no cointegration are rejected. The hypothesis of one cointegrating vector is accepted.

It is seen from Table 8.7 the Johansen cointegration results indicate that the wheat acreage model has one cointegrating vectors. It also means unique long-run equilibrium relationship exists.

Estimated long-run cointegrating vectors of wheat variables have been included in Table 8.8.

Table 8.8: Long-run Cointegrating Vectors (price vector with short-run coefficient)

Acreage	Prices		Irrigated area (Long-run)	Production (Long-run)	Yield (Long-run)	Adjustment coefficient of acreage
	Short-run	Long-run				
Wheat	0.14^{NS} (1.07)	0.25 (2.47)	0.67 (-4.26)	0.76 (-8.28)	1.06 (5.29)	near to zero 0.01 (-0.07)

Note: NS-Non significance, Figures in Parentheses show the value of t-statistics

Table 8.8 provides the long-run coefficient of price (P_w) of 0.25 (inelastic range) which is significant at 1 percent level. This implies that 1 percent increase in price level increases wheat area by 0.25 percent in the long-run. Other variables have positive impacts on wheat acreage. output or Production (Q_w) has positive impact on wheat area decision. The estimated coefficient for production (Q_w, is 0.76 and highly significant. Irrigated area (I_w) and yield rate (Y_w) also positively affect wheat area distribution with elasticity of 0.67 and 1.06 respectively and both are highly significant. If irrigated area increases 1 percent area of wheat will go up to 0.67 percent simultaneously.

It is seen from results that wheat supply is not responsive to its own price. Results suggest that government should take measure for increasing wheat production by introducing input support policy as well as expansion of irrigation.

The short-run acreage elasticity to price is 0.14, though it shows insignificant result. The wheat cointegration equation represents the long term adjustment coefficients. This show the extent to which the current change in vector (Z) is a response to the last time deviation to converge with the long term relation. The adjustment coefficient of wheat acreage (A_w) is near to zero. This indicates that these variables are determined by outside factors such as changes of cropping pattern, increasing demand for wheat as a regular food item.

It is a regular picture in our agriculture sector, during the wheat growing season, the distribution and availability of the right types of chemical fertilizers are always problem in Bangladesh. Bangladesh has to import all the required chemical fertilizers. Its delivery has distribution are handed by government agencies. Generally, the delivery of fertilizers to different sales centre at the district level is delayed. At the same thing, the availability of imported seed at affordable prices is another problem faced by Bangladeshi farmers. These constraints have helped dampen the price elasticity of wheat supply in Bangladesh in short-run and subsequently in long-run. Harvesting and threshing of rice grains coincided with the land preparation time for wheat cultivation. Marginal farmers always faced constraints in doing all activities within a limited time frame. In sum, the higher requirement of turnaround time between rice and wheat and the scarcity of farm resources has contributed to the reduction of price response of wheat supply in Bangladesh both in the short-run and the long-run.

8.6 Summary and Conclusions

On the basis of model specification, this chapter provides a time series analysis of acreage response for rice and wheat. The vital contents of this chapter are cointegration and ECM analyses of rice and wheat. The acreage response of aus rice depends on own price, irrigated area, output and yield rate. Chapter provides results of unit root tests of variables. We found in chapter 7 the evidence of non-stationarity in selected variables.

To overcome the spurious results from our analysis as a prior concern we introduced unit root test in chapter 7 as first step. In this respect ADF test is applied for checking unit root problem. If the existence of unit root is found we difference the data series to achieve stationary series. When we difference data series to make stationary, it losses valuable information from that series, as a part of analysis it is necessary to retain/regain missing long-run information by applying cointegration techniques.

In this chapter we estimate acreage response (functions) using cointegration technique and subsequently study estimates the corresponding ECMs. These tools provide the parameters of dynamics short-run and long-run relationships. Following the estimated parameter values from these equations normalized on acreage we obtain the long-run elasticities. The estimated coefficients of rice indicate that farmers in Bangladesh respond to price incentives. It is seen from results that aman acreage does not respond to price (inelastic range). Environmental characteristics and cropping pattern of Bangladesh agriculture are pertinent factors for area allocation of aman rice. It is needed to mention here that degrees of price responsiveness for each crop depend on some economic and demographic factors. These are position of the crop in agriculture, stages of commercialization, market demand of the respective crop, food culture of the country, finally, and availability of resources.

Results show that price policies, measures to increase improved yield technologies and irrigation development programs are effective instruments in increasing aus, aman and wheat acreage. Results imply that the responsiveness of irrigation to aman acreage is inelastic, because aman rice is being cultivated in rainy season. So irrigation is not a significant factor for aman acreage distribution case for Bangladesh.

Our results indicate that price factor of boro is almost responsive (near to unitary elastic range) to boro acreage distribution. It is mentionable here that irrigation schemes and technological improvement are important determining factors for wheat and aus rice acreage distribution as well as yield.

Following wheat results it shows less price responsive (inelastic range) to area allocation. In sum, limitations of time and scarcity of farm resources especially fertilizers and inadequate irrigation facilities have contributed to the reduction of price response of wheat supply in Bangladesh both in the short-run and the long-run.

In case of aus acreage takes eight years (adjustment coefficient 0.12) to achieve equilibrium. Aman acreage takes nearly four years (adjustment coefficient 0.27) for the system to return equilibrium. For boro acreage implies that area takes nearly three years (adjustment coefficient 0.37) to achieve equilibrium. Adjustment coefficient for wheat shows insignificant results and this indicates that wheat acreage variables are determined by outside factors such as changes of cropping pattern, increasing demand for wheat.

Finally, our estimated acreage elasticities with respect to price support previous empirical results (Hossain, 1984; Dorash, Shahabuddin and Rahaman, 2002; Begum *et al.* 2002; and Mushtaq, 2000). Boro and aus acreage elasticities in respect of price show comparatively higher values which are almost similar with previous studies. The evidence from the supply response studies on agro-based development countries shows that aggregate supply elasticities of agricultural output range from 0.3 to 0.9 (Thrilwal, 2003:202). Long-run elasticity is obviously higher than short-run elasticity, and elasticity tends to be higher in response to farmers to price changes depends crucially on the ability of infrastructure and access to agricultural inputs. In poorer countries with inadequate infrastructure, supply elasticity is low (0.2 to 0.5). In fact, the provision of public goods and supply elasticity of agriculture with respect to non-price factors (for example the provision of public goods and services) is much higher than it is with respect to price, especially in poorer developing countries with inadequate infrastructure and marketing facilities.

in a wide range of agricultural activities. In 2004-05 the combined contribution of all sub-sectors of agriculture to GDP is about 21.9 percent and the crop sub-sectors alone is projected to contribute 12.10 percent to GDP. The contributions of fisheries sub–sector to GDP and to agricultures are 3.3 percent and 10.33 percent respectively. The contribution of livestock sub-sector to GDP and to agricultural sectors are 3.2 percent and 10.11 percent respectively. About 63 percent of the labour forces are employed in agriculture with about 57 percent being employed in the crop sector.

In short, agriculture is the driving force behind economic growth in Bangladesh. As a result, increasing food and agriculture production has always been major concerns of policy makers. Within the crop sector, rice dominates with an average of 71 percent share of the gross output value of all crops. As a result growth in the agricultural sector essentially mirrors the performance of rice production.

This chapter covers characteristics of agriculture, factors related with crop production, government agriculture policy. Finally comprehensive and analytical discussions on agriculture pricing policy are discussed in this chapter.

Chapter 3 discusses theoretical issues on supply responses. It starts with classical theory of supply such as Law of Diminishing Returns. In real world, price and non--price variables affect the output supply. Factor identification of output supply on the basis of empirical background has been made in this chapter. This chapter provides a theoretical framework for supply response from various aspects.

It is important to identify specific variables that affect the output supply of any products. From the experiences of theoretical aspects it is needed to mention here that price of own products, competing crops prices, input prices, irrigation are the key variables of output supply. This chapter also covers the theoretical concept of elasticity of production and factors that determine elasticity of supply, because elasticities are frequently used for convenience to express the supply response to price.

Chapter 4 carries the summary of empirical works and related literature on supply response in Bangladesh. Most of the empirical works in the field of supply response have concentrated on acreage decision. All the previous studies on supply response are based on Nerlovian frame works and have used acreage response with the price changes. The supply response literature in Bangladesh shows that in the estimation procedures these studies have used traditional tools and techniques like OLS and simple linear equation. It is needed to say that these previous studies have used time series data irrespective of stationary and non stationarity. The outcomes of these studies in most of the cases are spurious. Most of the studies use acreage as the dependent variables for assessing farmers' output response to prices.

Chapter 5 provides the econometric methodology employed by this study in modelling the dynamic relationships of supply response. This chapter also discusses that economic time series often exhibit non stationarity stochastic processes. The noneconometric specification has been conducted in a framework that allows for non-stationary but potentially cointegrated variables. The approach adopted is to convert the dynamic model into error correction formulation. This formulation contains information on both the short-run and long-run properties of the model, with disequilibrium as a process of adjustment to the long-run model.

Time series analysis remains the most widely used approach for estimating supply response. Modern time series techniques offer new promise. Cointegration analysis can be used with non-stationary data to avoid spurious regressions. When combined with error correction models, it obtains consistent yet distinct estimates of both short-run and long-run elasticities. Hallam and Zanoli, (1992), Townsend and Thirtle (1994), and Townsend (1996) have used cointegration analysis and ECMs to estimate supply response at a commodity level, on the basis that they are preferable to traditional partial adjustment model.

The first step in cointegration analysis is to test the order of integration of the variables. A time series is said to be integrated if it accumulates some past effects, so that following any perturbance the series will rarely return to any particular 'mean' value and it will become non-stationary. The order of integration is given by the number of time a series needs to be differenced so as to make stationary. If series are integrated of the same order, a linear relationship between these variables can be estimated, and cointegration can be tested by examining the order of integration of this linear relationship.

Chapter 6 characterizes the basic statistical properties of the data, and illustrates how the data are obtained. The chapter has started with specification of the variables. It delineates the time series data. An elaboration description of the variables has been made in section 6.3. Simple statistical table and graphical trend of the time series variables have also been presented in this section.

Chapter 7 represents the unit root results of the variables. Practically, most econometric time series data show non-stationary trend. Any time series has a unit root where its first difference is stationary. In this study acreage, yield, price and irrigated area of rice and wheat are tested for unit roots using ADF test. The ADF test results in levels and first differences are given in section 7.3. The null hypotheses of unit root are accepted for all the variables in level form. When the procedure of ADF tests is applied to the first difference, these sequences are found stationary. In this stage we infer that the variables are all integrated of order-1.

Table 9.1: Long-run and Short-run Acreage, Price, Yield and Output Elasticities of Major Crops

Acreage	Prices		Irrigated area (long-run)	Production (long-run)	Yield (long-run)	Adjustment coefficient of acreage
	Short-run	Long-run				
Aus	0.12	0.98	1.09	0.28^{NS}	.0.95	0.12
Aman	0.06	0.31	0.34	0.14^{NS}	-	0.27
Boro	0.21	0.95	0.002^{NS}	0.07^{NS}	-	0.37
Wheat	0.14^{NS}	0.25	0.67	0.76	1.06	-0.013

Note: NS- Nonsignificant

The long-run own price elasticity of aus acreage is unitary elastic (marginally) with 0.98 and is significant. The short-run price elasticity is 0.12 and insignificant. Irrigation positively effects the aus acreage distribution. The estimated elasticities for irrigated area and yield rate of aus are 1.09 and 0.95 respectively. The acreage adjustment coefficient of aus of 0.12 suggests that it takes eight years to achieve equilibrium. It is seen from the Table 9.1, the long-run price elasticity is higher than short-run elasticity.

The long-run own price elasticity of aman is inelastic with a value 0.31 and which is significant at 5 percent level, and short-run elasticity is 0.06 at 10 percent significance level. Irrigated area positively affects the aman area distribution with inelastic value of 0.34 at 5 percent significance level. Production or output elasticity in respect of acreage distribution is low with 0.14 and insignificant. For aman, acreage adjustment coefficient is 0.27 and it takes nearly four years for the system to return to equilibrium.

The long-run price elasticity of boro is elastic with 0.95 and is significant and short-run elasticity is 0.20 at 5 percent significance level. Production (output) variable has a little impact on acreage distribution. The coefficients for output and irrigated area are 0.07 and 0.02 respectively and are insignificant. The area adjustment of boro rice is 0.37; it implies that area takes three years to achieve equilibrium after disequilibrium.

The long-run price elasticity of wheat acreage is inelastic 0.25 and is significant. The short-run price elasticity is 0.14 and insignificant. Production (output) variable has positive impact on acreage distribution. The estimated elasticity of output to acreage is 0.76 and elasticity of irrigated area to acreage is 0.67. Yield rate is elastic with a value of 1.06 to acreage distribution of wheat. Adjustment coefficient for wheat of about zero shows insignificant results. This indicates that wheat acreage variables are determined by outside factors. These factors include changes of cropping pattern, increasing demand for wheat and crop diversification.

9.3 Conclusions and Policy Implications

This study was designed to determine the rice and wheat supply response to selected factors to analyze the short-run and long-run supply responses of rice and wheat in Bangladesh.

On the basis of analysis, the estimated elasticities can be used to meet the objectives of this study. It is found that the range of the short-run elasticity is small in size (.06 to 0.21). A well managed irrigation facility is one of the limiting factors in Bangladesh agriculture. Another common problem is scarcity of inputs like land and capital are limited in the short-run. These limitations are cause of narrow range of elasticity in the short-run elasticity. But in the long-run the elasticity of supply increases with time, because farmers are able to adjust their fixed factors or inputs in production process. As a result the long-run supply elasticity becomes higher than the corresponding short-run elasticities.

9.3.1 Applicability of Price Policies

Our results show that farmers are responsive to own price in case of aus and boro rice though, aman results show less responsive to it own price. We know that any change in prices affects area and production in different ways. The nature of impact depends on types of crop, whether it complementary or competitive or unrelated. The event of price changes in any economy has multidimensional effects. It affects the allocation of land and other resources for that particular crop but also changes the land allocation of other crops. Crop diversification in any economy is extremely related with the effectiveness of price policies. Crop diversification is now expanding rapidly in Bangladesh agriculture sector. So the results of changes in prices of different crops on area distribution it leads to optimal cropping pattern in agriculture sector. Bangladesh now approaching commercialization of agriculture and in this stage farmer considers profitability, it compare with competitive and complementary crops in case of area allocation. Their primary objectives are to maximize output as well as to maximum return from particular crop. In this connection, the effectiveness of price policy and it impacts on area allocation are measured by magnitude of price responsiveness.

Wheat results show less price responsive (inelastic range) to area allocation. In the study, the possible reasons for short-run and long-run inelasticity of wheat supply in Bangladesh are: Wheat requires frequent, but well managed irrigation. Irrigation is one of the limiting factors in Bangladesh agriculture, especially in winter season. Farmers preferred to grow wheat in areas where reliable irrigation facility is available, since the irrigation water was very critical for the crop. In a situation where irrigation facilities is limited and in addition the period of wheat growing is very short in crop calendars in Bangladesh, as a result it is normal for the price response of wheat to remain at an inelastic range.

9.3.2 Technological policies

Our results support that irrigation (as a measure of technological progress) has a significant impact on area distribution of rice (except aman rice) and wheat. Technology and irrigation as non-price variables are important in explaining boro acreage and wheat acreage decision. Boro rice and wheat are specially grown in areas where adequate irrigation facilities are available. It is hypothesized that the requirements of irrigation facility may increase wheat and boro acreage. This argument indicates that if we want to achieve food self sufficiency, the prime concern could be technological improvements.These include irrigation infrastructure, improved certified seeds and introduce HYVs and thus, it will give positive impacts on wheat and boro rice production in the country.

We have seen from earlier discussion and it is experienced from the least developing countries that the supply response of farmers to price changes depends a great deal on the ability to respond, which in turn depends on infrastructure, transport, access to inputs and so on. Government may be in a dilemma here because raising producer prices and reducing their own revenue may impair their ability to spend on infrastructure and other facilities. Given that the elasticity of supply with respect to non-price factors is higher than with respect to price, it would seem unwise to cut public expenditure as far as it affects the agricultural sector.

9.3.3 Policy recommendations

Findings of this study express that supply (acreage) of aus and boro are responsive to their own prices. So their production through expanding of aus area can be increased by increasing their prices. However, the price change of these crops would affect the production of other crops due to negative cross-price elasticities. Price support for one crop may reduce production of other crop(s).

In case of wheat and aman rice are not price responsive. Due to cropping culture and favourable weather, aman rice has become a main crop since early history of Bangladesh agriculture. In that case input price support policy and technological implications are more effective for increasing overall supply of wheat and aman rice .

Our results also demonstrate technology and irrigation are key determinants for increasing for all crop area as well as supply. Supply elasticity of non price factors (irrigated area and yield) are relatively higher than with respect to price. So it is a prudent decision to increase public expenditure on irrigation schemes and other technological improvements.

9.4 Limitations of the Study and Future Research

This study has tried to apply recently developed econometric techniques to estimates supply response of major agricultural products in Bangladesh. The study overcomes spurious problem by applying cointegratioin techniques. Error correction mechanism has been used in explaining supply response of agricultural products and it produces acceptable results.

However the study has some limitations. This study includes rice and wheat as major crops in Bangladesh. Other crops are not included either due to the non-availability of required data or they contribute little to agriculture sector. Data on input prices are not available for fertilizer, pesticide and seed prices. Difficulties are faced in obtaining data on technological measurements. We only use on data irrigated area under rice and wheat as a measure of technological progress; Data on other technology variables are not available in Bangladesh. There are many determinants of supply that may affect crop supply that we have dropped due to above mentioned constraint.

At last a time series model accounts for patterns in the past movement of a variable and uses that information to predict its future movements. Time series data have become popular to be intensively used in empirical research and Econometricians have recently begun to pay very careful attention to such data. We firmly believe that this study has shed some important light on the subject area encompassing time series modelling to predict future food grain supply in response to government various agriculture policies. The empirical findings can be an important source of information to many researchers and policy formulators. The present study expected to provide useful data to the researchers and helped them in identifying future research problem.

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