Microeconometric Analysis of Food Security in Pakistan: Classical versus Bayesian Analysis

By

Rizwan Niaz

Department of Mathematics& Statistics
Faculty of Basic and Applied Sciences
International Islamic University, Islamabad
Pakistan

2017

Mathematical statistics.

Bayesian statistical decision theory.

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بسم الله الرحمن الرحيم

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A Dissertation
Submitted in the Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
IN
STATISTICS

Supervised by

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Certificate

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A DISSERTATION SUBMITTED IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF THE MASTER OF SCIENCE IN STATISTICS

We accept this dissertation as conforming to the required standard.

1. ______________________ 6/10/17
Dr. Zawar Hussain
External Examiner

2. ______________________
Dr. Ishfaq Ahmad
Internal Examiner

3. ______________________
Dr. Muhammad Akbar
Supervisor

4. ______________________
Prof. Dr. Muhammad Sajid, T.I
Chairman

Department of Mathematics & Statistics
Faculty of Basic and Applied Sciences
International Islamic University, Islamabad
Pakistan

2017

Dedication

My beloved parents, for they made me who I am

And

My respected teachers, for they have been a source of inspiration and guidance

Forwarding Sheet by Research Supervisor

The thesis entitled "**Microeconometric Analysis of Food Security in Pakistan: Classical versus Bayesian Analysis** " submitted by **Rizwan Niaz** (Registration#74-FBAS/MSST/F15) in partial fulfillment of M.S degree in Statistics has been completed under my guidance and supervision. I am satisfied with the quality of his research work and allow him to submit this thesis for further process to graduate with Master of Science degree from Department of Mathematics and Statistics, as per IIU Islamabad rules and regulations.

Dated: ____________________

Dr. Muhammad Akbar
Assistant Professor
Department of Math&Stat,
International Islamic University,
Islamabad.

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I also acknowledge my friends with whom I had a pleasant and fruitful company. Finally, I extend my acknowledgement and heartfelt love to my family members, especially my father, who have been spurring my spirits and supporting my research.

Rizwan Niaz

DECLARATION

I, Rizwan Niaz s/o Muhammad Niaz khan, a student of Master of philosophy at Islamic international university Islamabad Pakistan, do hereby solemnly declare that the thesis entitled "Microeconometric Analysis of Food Security in Pakistan: Classical versus Bayesian Analysis" submitted by me in partial fulfillment of the requirements for master of philosophy degree in statistics is my original work. It is also declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any university or equivalent institution, and that to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Rizwan Niaz

Signature: ____________________

Rizwan Niaz

MS (Statistics)

Reg. No: 74-FBAS/MSST/F15

Department of Mathematics and Statistics,

Faculty of Basic and Applied Sciences,

International Islamic University Islamabad, Pakistan.

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List of Abbreviations

ADB	Asian Development Bank
AMD	Agricultural Market Development
APCDC/Kcal	Average Per Capita Daily Consumed Kilo Calories
CDVM	Categorical dependent variable
FATA	Federally Administered Tribal Areas
FBS	Federal Bureau of Statistics
FS	Food Security
FS Levels	Food Security Levels
FSC	Food Security Centre
GOLOGIT	Generalized Ordered Logit Model
H	High
HH	Household
HHs	Households
IFPRI	International Food Policy Research Institute
Kcal	Kilo calories
KPK	Khyber Pakhtunkhaw
L	Low
LR	Likelihood Ratio
M	Medium
OL	Ordinal Logistic
PIHS	Pakistan Integrated Household Survey
PPO	Partial Proportional Odds
PRA	Parallel Regression Assumption
PSLM	Pakistan Social and Living Standard
SDPI	Sustainable Development Policy Institute
TCC	Total Calories Consumed
TEF	Total Food Expenditure

UN	United Nation
UNU	United Nation University
USCB	United States Census Bureau
VL	Very Low
WFP	World Food Progamme
WFS	World Food Summit
WHO	World Health Organization

Abstract

This study examines the situation of households' food security in Pakistan. Food security is a broad concept, encompassing issues related to the nature, quality, and security of the food supply as well as issues of food access and proper utilization. The world has been facing a paradox of wide spread food insecurity and malnutrition. Current studies shown that Pakistan is a low-income developing country with a per capita income , one of the lowest in the world but it generally has the economic ability to import the required food but still most of areas are food insecure in Pakistan mostly belong from province of Baluchistan . This study considers the main features of determinants of food security in Pakistan, particularly households' economy assessment, household income, household expenditure, employment status, region, dependency ratio etc are being considered indicators to measure the status of houschold in either food security or insecurity situation. And looks at what conclusions can realistically be drawn out of analysis when conducted within a conceptual framework. In this study average per capita daily kilo calories consumed index is used to measure food security at households' level, ordered logistic technique is used for analysis. For ordered we divide the households in four categories on the basis of our food security index that is per capita daily kilo calories consumed. Analysis of this study shows

32% people of Pakistan lie in very low category of food security mostly belongs from province Baluchistan and KPK also 29%, 19.2% & 19.5% lie in low, medium and high category respectively.

For conducting this study, PSLM (2013-14) survey data is used. Ordered logistic regression is used to conduct econometric analysis about households' food security in Pakistan also a Bayesian ordinal logistic regression with informative prior as well non-informative prior is used to conduct Bayesian analysis about households' food security in Pakistan. The model is finalized on the basis of 13 explanatory variables which are found to be highly significant for determining food security status at households' level these variables involve socio economic variables, different characteristics relating to households and heads of the households.

Chapter 1

Introduction

The purpose of this study is to determine the food security level of households in Pakistan. Food is an essential and basic requirement of the society and also it is included in the basic human rights. After the food crises in 1970 the concept of food security was highlighted to the front of world and made suitable programs to overcome this issue.

World Food Summit presented official definition of food security as: "Availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuation in production and price" (UN, 1975). In 1996 World Summit on Food Security stated that "food should not be used as an instrument for political and economic pressure". According to the International Centre for Trade and Sustainable Development, unsuccessful agriculture market regulation and the lack of anti-dumping mechanisms cause much of the world's food shortage and malnutrition.

Food security is defined as when all people acquire a safe, satisfactory, nutritious diet through a sustainable food system that maximize healthy choices many developing countries around the world, espccially in South Asia and Africa still haven't been able to get satisfactory food for their citizen and deprive from this vital need even today. There are four pillars of food security that are defined by the FAO and these pillars of food security are availability, access, utilization, and stability.

Food availability is the dimension of food security that refers to supply side of food security which is expected as sufficient quantities and quality food is provided for every citizen from domestic agriculture production or import also by food balance sheet, food market survey and agricultural production plant by these factors this dimension of food security can be assessed at different level. Similarly, this dimension at different levels has some indicators to measure food security that are food production, Staple food production, storage, population flows, consumption of food items, harvesting time etc. This is the dimension of food security that refers to supply side of food security and measured through production, distribution, and exchange of food, as sufficient production, proper food distribution and exchange of food are the most important factors to determine this dimension of food security. Food production is determined by a variety of factors in term of land ownership and use soil management also food must be distributed properly to different regions or nation and exchange of food is also an important factor of this dimension that can affect food security insufficient trading system and lacking of management of market institutions is a greater barrier for achieving food security.

Access of food is another important dimension of food security it can be determined by the expenditure and income of the households. Food access means people have enough resource to obtain quality food for active and healthy life. There are some indicators that are probably considered to measure this dimension they are as wages, per capita food consumption, employment and food prices etc. It is noted by the UN committee that reason of hunger and malnutrition are frequently not because of insufficient food but an inability to access for available food in a country or nation. Usually problem in access is due to poverty that means not enough money to purchase quality food. Households those have sufficient resource they can overcome in instability and shortage of food access and they maintain food for their requirements.

Food utilization is the dimension refers not only about how much food the people eat but also what and how they eat. Food utilization refers to the metabolism by individuals once there is food achieved by household, variety of factors influence the quality and quantity of food that reaches to the members of the household. Food utilization is affected by food safety as it is affected by preparation of food, Processing of food, and cooking of food in the community and households which means to get food security food which is being ingested should be safe and should be sufficient to meet the each individual's requirements. Some determinants of food utilization are education, nutritional value, sanitation and healthcare and accountability of theses determinants is important for food utilization. Education about nutrition and food preparation can affect food utilization and improve this pillar of food security education brings awareness among people about the utilization of food and by improving these determinants we can able to manage a pillar of food security.

Individuals or households of a community cannot be considering in food secure status until there is stability of availability, accessibility and proper utilization condition. Unemployment, political unsteadiness and market prices fluctuation are the major factor disturbing stability of the dimension of food security. This dimension of food security can be assessed by Global Information Early Warning System.

Pakistan suffers from food crisis which is quite unfortunate and shocking because Pakistan is an agricultural country. In spite of sufficient production malnutrition is persistently prevailing in the country which is a threat to food security. The extra-ordinary rises in food prices affect the purchasing power of the people which resist the economic access to food. The three major dimensions of food security including food availability, food accessibility and food absorption, further effected by certain factors which effect food security in Pakistan as well as responsible for increasing food poverty in this region. These different factors collectively contribute to food security.

Pakistan's agriculture sector is a main source of its economy and is critical to future improvements in economic growth, employment, food security and poverty reduction. In past decade unstable political and security atmosphere has slowed the investment and caused the human life and human capital, also natural disasters have resulted in displaced populations, badly influenced to the productive infrastructure, diverted the budgets and reduces in service. This diversion of the times has negatively impacted on Pakistan's economy and agriculture sector. Yet Pakistan's economy is now showing signs of reasonable growth, and there is potential to capitalize on this progress over the coming years. While the government of Pakistan remains strongly committed to the agricultural backbone of its economy, there is huge potential in this sector.

Fifty six million people living in urban areas of Pakistan, 21 million are food insecure on basis of calorie consumption. Condition is particularly severe in Baluchistan where 20 districts with urban population fall in the zone of food insecurity. In Sindh 6 and in NWFP 5 districts are food insecure (Government of Pakistan, 2011). Punjab province is comparatively better than others (Bashir *et al.*, 2012). Pakistan has the potential to become a completely food secure and prosperous country that allows high quality food on the table for everyone. Over the years, Pakistan has made gains becoming a food surplus country, and a major producer of wheat. However, 60% of the population is still facing food insecurity it is due primarily to inadequate economic access by the poorest and most vulnerable particular women to a sufficient and special diet.

It has been observed over the past few years' supply and demand imbalances are growing trend in food prices it has put many people at risk of food insecurity and poverty across all over the world. Food security is a serious issue in many developing countries and Pakistan is also affected and considered food insecure country the Government of Pakistan also realizes the importance of food security and envoys a high priority to it in development plan and policy formulation. Food security situation demands a comprehensive study of different dimension of food security continuous monitoring of its indicators and proper consideration of policy options. The analysis of food security is connecting in multidisciplinary various organizations and data agencies are being worked on food security analysis to overcome this issue of food security in a country.

The established Food Security Centre (FSC) at PIDE will develop such collaboration, conduct research on issues relevant to food security, and provide proper guidelines for designing a food policy. Pakistan is a developing country has many Problems, like unemployment, terrorism and many other issues, food security is an issue in Pakistan that arises due to in efficiency in dimension of food security that are access of food, utilization and stability. In our country it is challenge to maintain adequate food production for the growing population with the expected economic growth, and in the face of adverse climate impacts. There are a variety of challenges include rise human capital, political conflicts and instability, size of household and formal and informal social safety nets. In Pakistan unfortunately mostly households are not able to get sufficient food for their healthy life. Inadequate in their food due to not physical access to the food, no proper utilization of food due to illiteracy or they are not able to get food due to unemployment etc.

1.1 Objectives of the study:

The objectives of this study are

- Determinate the factors affecting households' food security.
- Estimation of the model by using classical as well as Bayesian inferential approaches.
- Selection of the best model and discussion about the results.
- Suggest policies to improve food security in Pakistan.

Chapter 2

Literature Review

2.1 Introduction:

There are number of studies available in literature that discuss the food security in Pakistan and also causes of food insecurity. Similarly, a vast array of literature is available on food security .We divide this chapter in subsections. Section one is introduction of the chapter. Second section contains basic concept of food security. Section three contains previous studies related to food security Pakistan in and section fourth contains previous studies related to food security in other countries and in last section we give the summary and conclusion of this chapter.

2.2 Basic Concepts of Food Security:

Availability, accessibility and consumption of the food is the basic concept of food security is being considered as a famous among researchers as a main pillar of food security (Andersen, 2009). Different types of phenomenon are made to measure level of food security with the passage of time these concepts have more elaborated form. After the global food crisis in 1970, food security issue has been treated a main factor in the progress of any country and continuously making plans to overcome this issue in all countries especially developing countries. Further it can be defined as it is a situation which exists when all people of a locality have physical, social and economic access to sufficient food at all times. Also safe and nutritious food available all times for all people in a particular areas that meets their dietary needs for their active lives but in some developing countries it has been noticed that food availability and per capita consumption are declining also not sufficient to fulfill the requirements of the healthy and active life (Deaton and Dreze, 2009).

2.3 Reviews of Studies in Pakistan:

Gera (2004) stated that food security exist when people all the times have economic physical access to have enough food for satisfactory, nutritious and safe food require for people for their active and healthy lives. In that study secondary data sets were used and results and figure indicated food insecurity in particular areas and it is suggested that its government responsibility to provide food security level for its citizens included all vulnerable people. Further it is suggested structural modification programs are required, such as sinking the budget deficit, have resulted in the elimination of subsidies on wheat and agricultural inputs.

Bajwa Bakhsh *et al.,* (2007) conducted the study to know about the food security problems of Pakistan. For this purpose there secondary data sets were used and some comparative analysis was made on the basis of the three basic core areas of food security i.e. Food availability, access and utilization. Analyzed facts and figures have shown that Pakistan is a food sufficient country because there is the high undernourished population due to the problem of food accessibility. All these data sets they examined was favoring that Pakistan overall national level, is a food sufficient country and one can reasonably conclude that food security is not a big problem for us but a high proportion of undernourished population delivers a few questions about the mechanism of food and income distribution. They also recommended some suggestions about these issues for example the gaps between incomes of different social groups must be shortened. Increase and sustain the food production for which farmers and researchers must be given some incentives.

According to Ahmad *et al.,* (2010) Pakistan is a low income country and its main sector is agriculture for food to its growing population. And cultivated area is just increased 40% during last 60 years; while it's rising population pressure affect the cultivated land. The paper highlighted the inferences of the government's present food security policies on the one hand; it is require much effort to taper the gap between population growth and domestic food production. They suggested that to manage food security issue in Pakistan need understanding about how agriculture policies influence food supply and income.

Niazi and Naeem (2010) conducted a study and identified that Pakistan is one of the foremost producers of important agriculture commodities but still has large proportion of people that are being listed in food insecure. For the analysis data primary data of households were collected from the district Faisalabad of the Punjab it was found that 18% of the households were food insecure and the situation of the rural areas was slightly better than urban areas. It was explored by the analysis that there are some factors which are positively affecting the food security and these factors are education level and household income on the other side some factors that are affecting negatively these factors are age of household's head family size and expenditure in the form of move etc. It was suggested that the primary and secondary education enrollment must be improved along with technical education facilities.

Sultana Kiani (2011) examined household's food security in Pakistan by using a technique logistic regression. PSLM (2007-08) survey data was used to conduct the analysis. Data was consisted on demographic indicators and some others variable that affect the food security. In this study dependency ratio also has a significant impact on food security and has expected sign that is negative also education of high level showed positive impact on food security while social capital and employment do not effect household's food security significantly. They suggested that to make country required some different polices about food security and need programs to hold country at food secure level.

Bashir *et al.,* (2012) analyzed that Pakistan has high proportion of undernourished population 26%. The purpose of the study was to determine foods security tendency in Pakistan in general. Logistic regression technique was used and Primary data were assembled from 1152 household in 12 districts of the Punjab province using questionnaire survey 23% of the sample households were measured to be food insecure. Analysis of this study has declared about some factors that are positively influencing in food security of households and these factors are included monthly income, education level and live stocks also some factors are indicated too that negatively affected on food security includes head's age , joint family system etc. It was suggested that further improvement in food security at household level by creating job opportunities and give more education to the people of household also make family planning to minimize dependency ratio to alleviate food insecurity.

According to Amir Shahbaz and Zafar (2013) food insecurity will become a main issue of world in future especially developing countries are most severely affected by this danger. The study was intended to analyze and indentify some suitable strategies for dealing with shortage of food in Pakistan. The research was carried out in which cross-sectional survey was employed. The data were collected through personal interviews form the Khyber Pakhtunkhwa (KPK) Province of Pakistan was analyzed for the study. The results of the study showed that there is the fluctuation in the prices of food also limited access to the market, lack of irrigational water and high cost fertilizer were leading problem in food security in Pakistan. It was suggested that government should take steps for the betterment of agriculture department also provide subsidies so that people easily can access to their food.

According to Mahmood Tabassum and Jabeen (2014) analyzed food security exist when people all the times have economic physical access to have enough food for satisfactory, nutritious and safe food require for people for their active and healthy lives. Food security status was analyzed by four units at different intangible level in term of regions, countries, household and individual. People of Pakistan don't have sufficient access to meet their proper nutrition's requirements. That studied was conducted to analyze key issues influencing food security. A sample size of 120 was selected from rural areas of Faisalabad through multistage technique also chi square technique was used to find connection between age, education and income of the respondents and their perception about food security from the study there were 63.3% descriptions contain food insecurity issues around their locality and they had faced the problem of food availability.

Afzal *et al.*, (2015) conducted the study to elucidate the food security status for this purpose they selected the areas of study from Gazipur district data were collected from 50 farmers using purposive random sampling questionnaire technique was used to collect data. It was used minimum calories requirements index to measure food security level of these farmers by the analysis it was found that near about 50% of the sampled farmers were food insecure. The study concluded that out of six variables , four variables level of education of household's head and annual income , live stock and annually expenditure had significant positive effect on household's food security.

2.4 Reviews of Studies of other countries:

Many studies are available about food security around the world we will consider some of them in our papers as a reference of previous study of researchers about food security as fallow.

Lovendal (2004) study was conducted in Nepal to identify the vulnerability and food insecurity.data were collected from the rural areas based on this analysis, it considers how these people cope during times of insufficient food production and earnings, and suggested actions that could be taken to reduce their vulnerability to become food insecure in the future. Many studies on poverty in Nepal in past decades have fully focused on determining the poverty line and find out the proportion of people living under this line study has greatly focused to the need for greater policy and program support to food security in Nepal.

Cook Frank *et al.*, (2004) they conducted a study at household level for the analysis purpose sample of caregivers of 11,549 children age's less than 36 were interviewed in central city. After the manipulation of the data results were given that 21.4% of households were food insecure and 6.8% from them were hunger. By the logistic regression finding shows that food insecurity is concerned with health problem for young, low-income households' children. Make certain food security program may reduce health problems.

Hadley and Patil (2006) they conducted the study in June-August 2005 in Tanzania. For the analysis of the study 206 households were interviewed the total sample included 449 women were selected randomly for the interview. After manipulation of the data it was concluded that women who are food-insecure in the post harvest season score higher on a measure of anxiety and depression. They concluded that food insecurity may be linked to poor diets, which in turn affect anxiety and depression also food insecurity especially during the dry season and they suggested that there are required some polices at government level to improve food security in Tazania and provide some suitable resources to get access of food for each household within the country.

Kaisi and Zoughbi (2006) conducted the study in Syria which examined food security issues at national level for the purpose of analysis secondary data was used of households of the Syria. From the analysis of the study results shown that Syria has still challenge to get secure food for the national level and facing food insecurity issues mostly rural areas are highly victim of insecurity issue because lack of awareness about food issues. It was suggested that this challenge of food security can be met through increasing awareness about food security issues, raising campaigns on the use of reasonable and satisfactory food.

Omonona *et al.*, (2007) conducted a study in Nigeria about food security situation data from the households were collected and concluded that food insecurity increased with increase of age of household head, household dependency ratio and low education also it declines in households with higher level of income and high education, for female head food security incidence is found to be high.

Rose-Jacobs Black *et al.*, (2008) studied the relationship between household food security status and developmental risk in young children is determined by this study. Data were collected through interviews consisting demographic question, the US food security scale and parents Evaluations of development status the target child of age 4-36 month-old from each household were weighed. It was found mostly children were on developmental risk they are from low level income of the households it suggested that public policies must be improved that ameliorate the household food insecurity.

Mjonono Ngidi *et al.,* (2009, July) they studied the food security in South Africa and data was collected from the households ,from that particular survey it was concluded that 58.5% households had food insecurity problem it was specified agriculture influence in food security was important and suggested that improvement in agriculture sectors can reduce that food insecurity within the country also there is required to pay attention for the promotion of non-farming activities as well, particularly those that are associated with the smallholder agricultural sector.

Wangthamrong (2010) conducted a study and examined that Thailand is a major food exporter and manufactures more than enough food as it is required for the country. The data was collected from the households of Thailand to study how is probability of a household affected by economic, social and demographic characteristics also probit model was used to analyze the results of the study and concluded that some characteristics including gender, education and income significantly affect on food security. It is suggested government should take some steps to improve household food security within the country.

Edame Ekpenyong *et al.,* (2011) they conducted the study in Africa. Basic dimensions of food security were examined by this study including availability, accessibility, affordability, preference, utilization and nutritional value and food system stability. To conduct analysis about the study, data was collected from secondary source it was concluded that within current global challenge of atmosphere change and its unfavorable effect on the status of food security and agricultural output, some appropriate steps to improve these sectors must be taken towards adjustment and mitigation.

Sabila (2014) they examined that the issue of food security has been of basic importance in Kenya. As a basic need, food has been a main discussion issue in various round tables held by food organizations like FAO,WFP and governments around the world. The intention of this study was to find out how political affairs, modernism, Economics, social cultural factors influence food security of households in Mount Elgon Sub county. The study examined the influence of political factors on household food security, to establish the influence of economic factors on household food security, to identify the influence of innovation on household food security, to recognize the influence of social cultural factors on household food security. The study was conducted using the survey research design. Data was collected from 151 rural households through the use of structured questionnaires. The survey employed a systematic random sampling technique to select the sample. The sub county was divided into twelve locations to make sure the sample was representative of the population. The study concerned both primary and secondary data sources. Primary data was collected using a combination of questionnaires and interview schedules which was tested for reliability and validity by carrying out a pilot study. The secondary data was taken from published thesis, academic journals, textbooks, government publications and internet. The data obtained was processed through tabulation and tallying, thereafter it was coded and analyzed by use of measures of central tendencies, dispersion, percentages as well as content analysis. The data was presented using tables and frequency distributions. The summary of the findings have also been outlined and discussed based on the variables under study. Conclusions have been made based on information given and concluded that political affairs, modernism, Economics, social cultural factors influence food security of households in Mount Elgon Sub county.

2.5 Summary and Conclusion:

Our main target is to measure food security in Pakistan in this chapter we discussed about the basic concept of food security, literature reviews about food security in Pakistan and also took some previous studies on food security in other countries of the world. From the literature of Pakistan there is no single study available in which Bayesian ordinal logistic is used so this study has advantage over all other studies that was done about food security issues in Pakistan.

Chapter 3

MATERIALS AND METHODS

3.1 Introduction:

This chapter holds discussion of the methodology used in this study. It is more divided into subsections. First part of this chapter discusses data source, categorization of variables for the analysis of food security in Pakistan from the collected data also specified the model for analysis. While the second section, discusses estimation methodology used in the study.

3.2 Model's specification:

Explanatory variables are selected on the basis of past studies in Pakistan from the literature, selected variables like income, education, employment, and live stock positively affected the food security also head age family size negatively affected on food security (Bashir *et al.*, (2012)). Also these variables are found to be highly significant on food security (Niazi and Naeem (2010)). Our explanatory variables capture the impact of food security and we chose some appropriate variables that are significantly affect the food security. For example if a family has high income they expend more on food also it is given in literature that in Pakistan households spend most of the part of income on food stuffs if family expenditures are high that means it has positive effect on food security. Education influence positively on food security as we know when a household has proper information about utilization of food it will lead a household to fall in food secure category and families those have live stock they are also probable to fall in food secure category because they can utilize their live stock to increase calories that lead to fall them in secure category it means household having lives stock influence positively on food security also households bave their own agriculture status they are probable for secure category as we know agriculture positively affect the food stuffs and on daily required calories we also include household age in literature it is negatively affect on status of food security as when a person is old his concentration about food stuffs may not be appropriate also when family size of household is high it is probable to high dependency ratio that may also lead to fall in insecure category. Mathematically we can write our model as,

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_1 + \beta_3 X_3 + \cdots + \beta_{13} X_{13} \ldots\ldots\ldots\ldots\ldots \; 3.1$$

where Y= Food security status (1, if household is very low food secure; 2, if household is low secure; 3, if household is medium food secure; 4, if household is high food secure. Description of explanatory variables are given in Table 3.3

3.3 Data and construction of variables:

Table 3.1 Description of explanatory variables

Variables	Variables label	Codes	Desciption
X_1	Log-Income of household's head (Monthly)		Log of income per month
X_2	Log-Monthly expenditure		Log of expenditure per month
X_3	Household's size		No. of people in a household
X_4	Region		1=Urban, otherwise 0
X_5	Live stock	0=No, 1= yes	1= have live stock otherwise 0
X_6	Employment status	0=no,1=yes	1=employed otherwise 0
X_7	Age of household head		Head age in years
X_8	Gender of household's head		1=male otherwise 0
X_9	No. of children		Total children in a household
X_{10}	Agriculture status	0= No,1= yes	1= have agr. Status otherwise 0
X_{11}	Marital status		1=married otherwise 0
X_{12}	Education		Classes in years
X_{13}	Province		1=kpk otherwise 0 1=Punjab otherwise 0 1=Blochistan otherwise 0 1=Sindh otherwise 0

Data of all variables are collected from Household Integrated Expenditure Survey (HIES) 2013-14.The household survey is brought out by the Federal Bureau of Statistics, Government of Pakistan and provides the all-around data of household familiar variables. It is considerable enough sample size from this survey is to obtain concrete and competent results 17989 households were available in Household Integrated Expenditure Survey (HIES) for the year 2013-14 out of which 16554 were selected absolutely for the analysis. HISE data provides different socio economic variables for example household's income, consumption expenditure and consumption pattern, by the help of given information in HISE we selected some appropriate household to measure food security in Pakistan.

After selecting the appropriate households from the Household Integrated Expenditure Survey (HIES) for the year 2013-14 for analysis. We are interested to find food security in Pakistan. Food security status of households can be determined on the basis of average per capita daily kilo calories consumed by each member of a household.

The (HISE) data gives us number of quantities of different food items that were consumed by each household. To conduct the analysis of food security for this purpose, these food quantities that were consumed by each household we converted them into energy intake measured in kilo calories unit using food composition table for Pakistan (UNICEF and GOP, 2001) which includes data of nutrient contents of various foods. After converting food quantities into kilo calories we model food energy intake empirically.

We have calculated total calories consumed by each household's members for a month then divide by 30.4 to get per day calorie availability to households. Our indicator of assessing food security of households in Pakistan is that daily energy consumption per capita. This indicator is calculated by dividing each household's daily food energy availability by the number of household members (IFPRI 2007).

According to the IFPRI (2007) there are average requirements for light activity, at 2,050 kCal, serves as a benchmark category for the very low level food security for the developing countries which exceed 3,400 daily consumed kcal, serves as a upper benchmark (von Braun et al. 2005) . Our food security frame work is we find average per capita daily kilo calories consumed by each household.

If the Kilo calories of the household is less than 2,000 will be considered very low food secure ,If it is between 2,000 to 2,500 will be consider low food secure and if it is between 2,500 to 3000 is called medium food secure and if it lies more than 3,000 will be high food secure. It is important to note that requirements of food vary from age group as well sex and physical activity and psychological needs so we have calculated calories for each requirements, gender and different age groups.

Our dependent variable has 4 categories, as shown below in Table 3.2

Table 3.2 Food security status of households

Food security indictor	Bench mark for APCDC/Kcal	Values of FS levels
Very low (VL)	< 20,00	1
Low (L)	2,000 --- 2,500	2
Medium (M)	2500 --- 3,000	3
High (H)	+3,000	4

There are many indexes that are used to measure food security status some famous indexes that are frequently used are CCA approach (cost calories approach), APCDC/Kcal (average per capita daily consumed kilo calories approach), AHFSI (average household food security index) and FIVMS ((food insecurity and vulnerability and mapin system) these all are used to measure food security as we know food insecurity and hunger cannot be captured by any single indicator. To determine food security status at household level variety of conditions involved for example food is consumed by any household was it adequate in quality or in quantity? Can household members bring sufficient food for active and good health at home? if the household used any food how much the quantity of any food item was consumed? It means how much food is served in a household but also it's an important that after serving all food items by any household the effect of food items will vary individual to individual within a household such kind of all information is required to make a proper and valid conclusion about food security status at household level within a country. For this purpose variety of indexes are available in studies and we have to choose the best one among them which can produce better results so on the basis of that we able to make valid predication. Among all approaches that are used to measure food security we chose APCDC/Kcal index which has better indicators to measure food security. In this approach we collect all information from the household what they have consumed, after getting information about consumed items then we find kilo calories of these consumed items. Further in this approach we find calories at each age group and gender as we know effect of consumed item by any individual has different effect in term of gender, age and health. That's why APCDC/Kcal is the best approach to measure food security at household level within a country also IFPRI (2007) recommended this approach to check food security status of the household within acountry.

3.4 Methodology Of Analysis:

3.4.1 Ordered Logit Models:

In some cases response categories are naturally ordered. The dependent variable is discrete as well as ordinal. Ordinal models that keep the ordinal structure of the dependent variable in ordinal case where the dependent variable has at least 3 categories with these categories arranged in ordinal form i.e disease (mild, moderate, severe) or educational level (primary, middle, high). "When in data there is ordinal categorical form, we can use ordered probit model and odered logistic model but in literature ordinal logistic regression model is often preferred over the ordinal probit model in statistical applications, because its regression coefficients are more interpretable than ordered probit model (Zucknick and Richardson 2014)".

Logistic models are used with single dependent variable and a variety of independent variables. in logistic model we take logarithm to express dependent variable as the linear function of the independent variables, therefore logit model is the member of "generalized linear models" family.

Ordinal Regress is another extension of binomial logistic regression ordinal regression is used to forecast the single dependent variable with 'ordered' multiple categories and a variety of independent variables which means that different level of dependent variable are being measured by a variety independent variables. For example there a question is being asked from the respondent and answer lies between low and high, these two categories from the collected information didn't help us to generalize well, later we added levels to our response such as very low, medium and high and these are in ordered and ordinal logistic regression addresses this fact means ordered of the categories so in such situation we will prefer ordered logistic regression for the predictive purpose of dependent variable.

There is variety of ordinal models to measure categorical dependent variable like Continuation Ratio Model , Adjacent-Category Logit and Cumulative Logit Models are famous , usually Cumulative Logit Models are applied because these model easily interpretable. Cumulative models are further divided in 3 groups Proportional Odds Model, Non-Proportional Odds Model and Partial Proportional Odds Model. Cumulative Logit Models do work under the assumption of cumulative logit parallellity but parallel lines assumption sometimes does not hold; in this case Proportional Odds Model gives inaccurate results. Therefore models that reflect on ordinal structure and relax the assumption are recommended. NPOM and PPOM are recently used for this purpose.

In Our study ordinal dependent variable has C numbers of categories. We introduce a latent variable to define our categorical dependent variable, following long and Freeese (2001). Latent variable as l ranging between -∞ and ∞, also structural model can be given by

$$l = \beta X + \epsilon \text{.............................} (3.2)$$

here X is the matrix of k independent variables and β is the vector coefficient and ϵ is the random error term having logistic distribution and γ_c is threshold parameter which will change for each category. Our dependent variable Y is defined as fallow

$$
Y = \begin{cases} 1 = \text{if} - \infty < l < \gamma_1 \\ 2 = \text{if} \quad \gamma_1 < l < \gamma_2 \\ \quad \vdots \\ C = if\ \gamma_{C-1} < l < \infty \end{cases} \qquad (3.3)
$$

That means l is categorized by thresholds into C intervals, corresponding to these C ordered categories. The first threshold γ_1 takes the upper bound of the interval corresponding to observed outcome 1. Similarly, threshold γ_{C-1} shows the lower bound of the interval corresponding to observed outcome C. Threshold γ_c defines the Boundary between the interval corresponding to observed outcomes C - 1 and c for $(c = 1,2,\ldots,C - 1)$. Threshold parameters are

$\gamma^t = (\gamma_{min} < \gamma_1 \ldots\ldots\ldots < \gamma_{max})$ min = -∞ & max ∞

3.4.2 Assumption of Ordinal Logistic Model:

1) OLS regression is a non-Liner probability model and there is no liner relationship between dependent and independent variables.
2) In the case of ordinal variable, the variance of error term is no more homoskedastic.
3) Random disturbance term doesn't need to possess a normal distribution.
4) The ordered logistic model make assumption (PPA) .which suggests that all the slope parameters β's are same across each category of dependent variable. This suggests that most of liner predictors are the same for each category.

3.4.3 Cumulative Logit Models:

A variety of formats that can be used to predict the dependent variable when it is in ordered but cumulative logit models are preferred because they are the easiest to apply also when it comes to understand we can easily interpret. There are '$C - 1$' ways to compare 'C' categorized ordered dependent variable Y. similar to the other models, one category is selected as the reference category generally there is the highest category is selected as the reference category. '$C - 1$' cut-off points are estimated this way and the estimations give information for each consecutive category about cumulative probabilities(O'Connell, 2006). Cumulative logit model is derived from logit link function as shown in Equation (3.4).

$$logit[(Y \leq c/x)] = log[\frac{p(y \leq c/x)}{1-p(y \leq c/x)}] \quad c = 1,2,3 \ldots\ldots, C-1 \ldots\ldots\ldots\ldots\ldots\ldots (3.4)$$

Since the log odds for the event $Y \leq c/x$ is the ratio $\frac{\tau_c(x)}{1-\tau_c(x}$, where $\tau_c(x) = \pi_1(x) +$

$$\pi_2(x) + \pi_3(x) \ldots\ldots\ldots \pi_c(x)$$

$$log\, [\frac{\tau_c(x)}{1-\tau_c(x)}] = log\, [\frac{\pi_1(x)+\pi_2(x)+\pi_3(x)\ldots\ldots\pi_c(x)}{1-\pi_1(x)+\pi_2(x)+\pi_3(x)\ldots\ldots\pi_c(x)}]$$

Let $\tau_c = \pi_1(x) + \pi_2(x) + \pi_3(x) \ldots\ldots\ldots \pi_c(x)$, then $\tau_1 = \pi_1(x)$,

$\tau_2 = \pi_1(x) + \pi_2(x)$ and $\tau_C = \pi_1(x) + \pi_2(x) \ldots. \pi_C(x) = 1$

The ordinal logistic regression model in our setting is given as follows:

$$logit(\tau_1) = log\, [\frac{\tau_1}{1-\tau_1}] = \gamma_c - \beta X$$

$$logit(\tau_2) = log\, [\frac{\tau_2}{1-\tau_2}] = \gamma_2 - \beta X$$

...

$$logit(\tau_{C-1}) = log\left[\frac{\tau_{C-1}}{1-\tau_{C-1}}\right] = \gamma_{C-1} - \beta X$$

where $\tau_c = \pi_1(x) + \pi_2(x) + \pi_3(x) \ldots\ldots\ldots \pi_c(x) = \frac{\exp((\gamma_c - \beta X)}{1+\exp((\gamma_c - \beta X)}$, $c =$

$1,2,3 \ldots\ldots, C-1$

Every single cumulative logit has its own threshold value. When showing categories as $c = 1,2,3 \ldots\ldots, C-1$

$$\tau_c = \frac{\exp((\gamma_c - \beta X)}{1+\exp((\gamma_c - \beta X)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.5)}$$

Equation (3.5) derived from cumulative response probability for the c category of the ordinal outcome Y is

$$P(Y \leq c/\beta, b) = P(l \leq c/\beta, b) = P(\beta X + \varepsilon \leq \gamma_c)$$

$$P(\varepsilon_{ij} \leq \gamma_c - \beta X), \text{ for } c = 1,2,3 \ldots\ldots, c-1,$$

$$\tau_c = \frac{\exp((\gamma_c - \beta X)}{1+\exp((\gamma_c - \beta X)}$$

Equation (3.5) can be transformed to linear form via calculating natural logarithms of the odds ratios

$$log\left[\frac{\tau_c(x)}{1-\tau_c(x)}\right] = log\left[\frac{\frac{\exp(\gamma_c - \beta X)}{1+\exp(\gamma_c - \beta X)}}{1-\frac{\exp(\gamma_c - \beta X)}{1+\exp(\gamma_c - \beta X)}}\right] = log\,[\exp(\gamma_c - \beta X)]$$

$$(\gamma_c - \beta X) \quad c = 1, 2, 3 \ldots\ldots C-1 \ldots\ldots\ldots\ldots \text{(3.6)}$$

There are three main categories according to parallel assumptions and logit models are divided in these 3 models according to parallel assumptions name of the models are as fallow,

1) Proportional odd model proposed by (McCullagh,1980).
2) Non-proportional odd models proposed by (Fu, 1998).
3) Partial proportional odd models proposed by (McCullagh, 1980; Fu, 1998; Peterson and Harrell, 1990).

3.4.4 Parallel Lines Assumption:

It is an essential assumption in ordinal logistic regression that is slope parameters of the model should not be changed for each categories of the response variable. Also it means that the relationship between independent variable and dependent variable does not change for each category. Further we can say when assumption holds then the parameter estimation doesn't change for cut off points. When 'C' categorized variable, α_{C-1} cut-off points and β parameters hold parallel assumption at this point ordinal logistic model differs from multinomial logistic regression.

When this assumption about the parameters does not hold it means that there are no parallellity between categories. Some related tests that are recommended to check the parallel lines assumption like Likelihood Ratio Test, Wald Chi-Square test (Long, 1997; Agresti, 2002).

3.4.5 Proportional Odd Model (POM)

When it is found that parallel lines assumption holds in ordinal dependent variable, Proportional Odds Models are commonly used (Brant, 1990; Bender and Grouven, 1998). The ordinal logistic model is referred to explicitly as: In 1980 McCullagh proposed POM for ordinal regression based of such kind of model is cumulative distribution function. Proportional odds models can be estimated using cumulative probabilities (Kleinbaum and Ananth, 1997) given in Equation (3.7).

$$P\,[Y \le y_{j/x}] = \tau_j \quad = [\frac{\exp(\alpha_j - x'\beta)}{1+\exp(\alpha_j - x'\beta)}]\ j = 1,2,3 \ldots\ldots J-1 \ \ldots\ldots\ldots\ldots (3.7)$$

here unknown parameter's estimator of threshold is α_j and index $j = 1,2,3 \ldots\ldots J-1$ for $\alpha_1 \le \alpha_2 \le \alpha_3 \ldots\ldots\ldots \alpha_{J-1}$ also β is the vector of parameters of explanatory variables and shown as $\beta = (\beta_1, \beta_2 \ldots\ldots \beta_k)'$. The model can be transformed to linear form via calculating natural logarithms of the odds ratios. (Kleinbaum and Ananth, 1997) given in Equation (3.8).

$$(\alpha_j - x'\beta)\ j = 1,2,3 \ldots\ldots J-1 \ldots\ldots\ldots\ldots\ldots\ldots (3.8)$$

3.4.6 Estimation of Parameters of Proportional Odd Model:

Suppose that the k ordered categories of the response have probabilities $\pi_1(x), \pi_2(x), \pi_3(x), \ldots\ldots\ldots, \pi_k(x)$ when the covariates have the value x. Let Y be the response which takes values in the range $1,2,\ldots,k$ with the probabilities given above and let the response cell counts be $\{n_{ij}\}$ with row totals n_1, $n_2 \ldots\ldots n_k$ and column or category totals $\{n_{.j}\}$. Let R_{ij} be the cumulative row sums, therefore $n_i = R_{ik}$ is the ith row total. Under the assumption of multinomial sampling in each row, the marginal distribution of R_{ij} conditional only on the row total n_i is multinomial with index n_i and parameter τ_{ij}.

When more than one observation on Y occurs at a fixed $X^{(v)}$value, it is sufficient to record the number of observations $n_j^{(v)}$and the number of "j" outcomes, for$j = 1.2.3..k$. Thus we let $Y^{(v)}$ refers to these counts rather than to individual binary responses. The $\{Y^{(v)}, v = 1,...,n\}$ are independent multinomial random variables $Y^{(v)}$ ~ multinomial $(n_1^{(v)}, n_2^{(v)},\ldots\ldots. n_k^{(v)})$ where $n_1^{(v))} + n_2^{(v)}+\ldots\ldots.+n_k^{(v))}=1$. we define

$$R_1^{(v)}= n_1^{(v)}$$

$$R_2^{(v)}= n_1^{(v)} + n_2^{(v)}$$

.

$$R_k^{(v)}= 1$$

Since we are dealing with cumulative probabilities, in terms of the parameters of the cumulative transformation, the likelihood can be written as the product of $k-1$ quantities (McCullagh (1980)).

$$l = \prod_{v=1}^{n}\left\{\left(\frac{\tau_1{}^{(v)}}{\tau_2{}^{(v)}}\right)^{R_1^{(v)}}\left(\frac{\tau_2{}^{(v)} - \tau_1{}^{(v)}}{\tau_2{}^{v}}\right)^{R_2^{(v)}-R_1^{(v)}}\right\}\times\left\{\left(\frac{\tau_2{}^{(v)}}{\tau_3{}^{(v)}}\right)^{R_2^{(v)}}\left(\frac{\tau_3{}^{(v)} - \tau_2{}^{(v)}}{\tau_3}\right)^{R_3^{(n)}-R_2^{(v)}}\right\}\ldots\ldots\ldots\ldots$$

$$\times\left\{\left(\frac{\tau_{k-1}{}^{(v)}}{\tau_k{}^{(v)}}\right)^{R_2^{(n)}}\left(\frac{\tau_{k-1}{}^{(v)} - \tau_k{}^{(v)}}{\tau_k{}^{(v)}}\right)^{R_{k-1}^{(v)}-R_k^{(v)}}\right\}$$

$$logL=\sum_{v=1}^{n}\{R_{v1}\ log(\tau_{v1}) + (R_{v2} - R_{v1})\ log(\tau_{v2} - \tau_{v1}) - log(\tau_{v2}) +$$

$$R_{v2}\ \log(\tau_{v2}) + (R_{v3} - R_{v2})\ log(\tau_{v3} - \tau_{v2}) - log(\tau_{v3}) + \cdots +$$

$$R_{v,k-1}\ log(\tau_{v,k-1}) + (R_{v,k-1} - R_{v,k})log\ ((\tau_{v,k} - \tau_{v,k-1}) - log(\tau_{v,k})\}$$

$$logL=\sum_{v=1}^{n}\{R_{v1}\ log(\tau_{v1})+(R_{v2}-R_{v1})\,log(\tau_{v2}-\tau_{v1})+$$

$$R_{v2}\ log(\tau_{v2})+(R_{v3}-R_{v2})\,log(\tau_{v3}-\tau_{v2})+\cdots+R_{v,k-1}\ log(\tau_{v,k-1})+(R_{v,k-1}-$$

$$R_{v,k})log\ ((\tau_{v,k}-\tau_{v,k-1}))\}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.9)$$

$$\text{Log}L=\sum_{v=1}^{n}\left\{R_{v1}\ log\left(\frac{\exp(\alpha_1-x'\beta)}{1+\exp(\alpha_1-x'\beta)}\right)+(R_{v2}-R_{v1})\,log\left(\frac{\exp(\alpha_2-x'\beta)}{1+\exp(\alpha_2-x'\beta)}-\right.\right.$$

$$\left.\frac{\exp(\alpha_1-x'\beta)}{1+\exp(\alpha_1-x'\beta)}\right)+R_{v2}\ log\left(\frac{\exp(\alpha_2-x'\beta)}{1+\exp(\alpha_2-x'\beta)}\right)+(R_{v3}-R_{v2})\,log\left(\frac{\exp(\alpha_3-x'\beta)}{1+\exp(\alpha_3-x'\beta)}-\right.$$

$$\left.\left.\frac{\exp(\alpha_2-x'\beta)}{1+\exp(\alpha_2-x'\beta)}\right)+\cdots+(R_{v,k-1}-R_{v,k})log\ \left(\left(1-\frac{\exp(\alpha_{k-1}-x'\beta)}{1+\exp(\alpha_{k-1}-x'\beta)}\right)\right\}$$

$$\text{Since } log\left(\frac{\exp(\alpha_2-x'\beta)}{1+\exp(\alpha_2-x'\beta)}-\frac{\exp(\alpha_1-x'\beta)}{1+\exp(\alpha_1-x'\beta)}\right)=log\,\frac{\exp(\alpha_2-x'\beta)-\exp(\alpha_1-x'\beta)}{(1+\exp(\alpha_2-x'\beta))(1+\exp(\alpha_1-x'\beta))}$$

$$=log\,\frac{\exp(-x'\beta).\exp(\alpha_2)-\exp(\alpha_1)}{(1+\exp(\alpha_2-x'\beta))(1+\exp(\alpha_1-x'\beta))}$$

The log likelihood function is

$$\text{Log}L=\sum_{v=1}^{n}\{R_{v1}\,(\alpha_1-x'\beta)-log(1+\exp(\alpha_1-x'\beta))+(R_{v2}-R_{v1})(-x'\beta+$$

$$\log(\exp(\alpha_2)-\exp(\alpha_1))-log(1+\exp(\alpha_2-x'\beta)-log(1+\exp(\alpha_1-x'\beta))+$$

$$(R_{v3}-R_{v2})(-x'\beta+\log(\exp(\alpha_3)-\exp(\alpha_2))-log(1+\exp(\alpha_3-x'\beta))-log(1+\exp(\alpha_2-x'\beta))+\ldots-(1-$$

$$R_{v,k-1})log\ ((1+\exp(\alpha_{k-1}-x'\beta))\}\ldots\ldots\ldots\ldots\ldots(3.10)$$

From Equation (3.10) we can estimate the parameters by differentiating the likelihood with respect to unknown parameters.

3.4.7 Non-Proportional Odds Model (NPOM):

When parallel lines assumption does not hold in ordinal dependent variable then in this situation we can be used multinomial technique but in multinomial study we ignore the ordinal structure of the categorical dependent variable and assume it as a nominal variable so when the assumption does not hold and we use multinomial analysis it causes information loss. At this point it is suggested a new model that can relax the assumption about the parallel lines in ordinal formation this model is proposed by Fu (1998), and it is called Non-Proportional Odds Model. in this model β coefficients will change for every single category of the response variable it is shown as m (m $= 1, 2, 3 \ldots\ldots M - 1$) (Fu, 1998).

The difference between POM and NPOM is that NPOM has different parameters for every single category of tbe dependent variable. It is shown in Equation (3.11) the cumulative probability equation for NPO (Generalized Ordinal Logit Model).

$$P[Y \leq y_{m/x}] = [\frac{\exp(\gamma_m - x'\beta)}{1+\exp(\gamma_m - x'\beta)}] \text{ m } = 1, 2, 3 \ldots\ldots M - 1 \ldots\ldots\ldots\ldots\ldots\ldots(3.11)$$

where unknown parameter's estimator of threshold is γ_m and $\gamma_1 \leq \gamma_2 \ldots\ldots\ldots \leq \gamma_{m-1}$ ordered threshold. Vector of regression coefficients are $\beta = (\beta_{1m} \ldots\ldots\ldots \beta_{mk)},$ The model cab be transformed via calculating the natural logarithm of the odds ratio and it will take the linear form as shown below.

$$(\gamma_m - x'\beta) \text{ m } = 1, 2, 3 \ldots\ldots M - 1 \quad \ldots\ldots\ldots\ldots\ldots(3.12)$$

In this case of NPOM every single cumulative logit has its own threshold value.

3.4.8 Partial Proportional Odds Model (PPOM):

It is proposed by Peterson and Harrell (1990) and PPOM can be used when parallel lines assumption holds or not. PPOM tolerates the same characteristics with both POM and NPOM. Constrained odds model and unconstrained odds model are two types of PPOM by Peterson and Harrell (1990) and parameters estimation of the model can be done by maximum likelihood method.

3.4.9 Constrained Partial Proportional Odds Model (CPPOM):

The Model becomes constrained when the coefficients at the changing break points are multiplied with a predefined constant scalar. General form of the model proposed by Peterson and Harrell (1990) is shown in Equation (3.13).

$$P\left[Y \leq y_j \,/\, x\right) = \frac{\alpha_j - x'\beta - g'\lambda\Gamma_j)}{1+\exp\left(\alpha_j - x'\beta - g'\lambda\Gamma_j\right)} \qquad j = 1,2 \ldots\ldots k, \ \ldots\ldots\ldots\ldots\ldots\ldots(3.13)$$

here α_j is unknown parameter's estimator of threshold and x is the vector of explanatory variables size $(p\times 1)$ that point where parameters holding the parallel lines assumption also g is the vector of explanatory variables of size $(q\times 1)$ that point parameters which is not holding the parallel lines assumption and λ vector multiply by Γ_j (constant scalar) . The model is transformed by calculating the natural logarithm of the odds ratio and it will take the linear form shown in Equation (3.14).

$$(\alpha_j - x'\beta - g'\lambda\Gamma_j) \quad j = 1,2 \ldots\ldots k, \ \ldots\ldots\ldots\ldots\ldots(3.14)$$

3.4.10 Parameters estimation of constrained Partial proportional odd model:

Using Equation (3.9)

$$\text{Log}L = \sum_{v=1}^{n} \{R_{v1}(\alpha_1 - x'\beta - g'\lambda\Gamma_j) - log(1 + \exp(\alpha_1 - x'\beta - g'\lambda\Gamma_j)) + (R_{v2} - R_{v1})(-x'\beta +$$

$$\log(\exp(\alpha_2) - \exp(\alpha_1)) - log(1 + \exp(\alpha_2 - x'\beta - g'\lambda\Gamma_j) - log(1 + \exp(\alpha_1 - x'\beta - g'\lambda\Gamma_j)) +$$

$$+(R_{v3} - R_{v2})(-x'\beta + \log(\exp(\alpha_3) - \exp(\alpha_2)) - log(1 + \exp(\alpha_3 - x'\beta - g'\lambda\Gamma_j)) - log(1 + \exp(\alpha_2 - x'\beta)) + \dots -$$

$$(1 - R_{v,k-1})log((1 + \exp(\alpha_{k-1} - x'\beta - g'\lambda\Gamma_j))\} \dots\dots\dots\dots (3.15)$$

To get the estimators of the covariance matrix of the estimated coefficients in the usual way by evaluating second order partial derivatives with respect to unknown parameters of the models.

3.4.11 Unconstrained Partial Proportional Odds Model (UPPOM):

Two types of coefficient are estimated in such model first set of parameters that holds parallel line assumption and other set doesn't hold. Equation (3.16) shows the general form of the model.

$$P[Y \leq y_j / x] = \frac{\exp(\alpha_j - x'\beta - g'\lambda_j)}{1 + \exp(\alpha_j - x'\beta - g'\lambda_j)} \; j = 1,2 \dots\dots k \dots\dots\dots\dots (3.16)$$

where α is unknown parameter's estimator of threshold, x is (p x 1) vector of explanatory variables contains parameters which are holding parallel line assumption and g is (q x 1) vector of explanatory variables contains parameters which do not hold parallel line assumption. Also q is smaller than p there is only one subset of parameters will be non-proportional, therefore model becomes PPOM. In this equation λ_j is related with the coefficients and defines increment changes in logit for non-proportional variables. If λ_j is equal to 0, parallel lines assumption holds and model turns out to be POM. The model can be transformed by calculating the natural logarithm of the odds ratio and it will take the linear form in Equation (3.17).

$$(\alpha_j - x'\beta - g'\lambda_j) \quad j = 1,2 \ldots\ldots k, \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3.17)$$

3.4.12 Parameters Estimation of Unconstrained Partial Proportional Odd Model:

$$P\,[Y \leq y_{j/x)}] = \log\left[\frac{p(y \leq j/x)}{1-p(y \leq j/x)}\right] = \log\left[\frac{\pi_1(x)+\pi_2(x)+\pi_3(x)\ldots\ldots\pi_j(x)}{1-\pi_1(x)+\pi_2(x)+\pi_3(x)\ldots\ldots\pi_j(x)}\right]$$

$$\tau_j = \left[\frac{\exp(\alpha_j - x'\beta - g'\lambda_j)}{1+\exp(\alpha_j - x'\beta - g'\lambda_j)}\right] j = 1,2,3 \ldots\ldots k$$

Now using Equation (3.9) we can estimate the parameters as

$$logL = \sum_{v=1}^{n}\{R_{v1}\,log(\tau_{v1}) + (R_{v2} - R_{v1})\,log(\tau_{v2} - \tau_{v1}) + R_{v2}\,log(\tau_{v2}) + (R_{v3} - R_{v2})\,log(\tau_{v3} - \tau_{v2}) + \cdots + R_{v,k-1}\,log(\tau_{v,k-1}) + (R_{v,k-1} - R_{v,k})log\,((\tau_{v,k} - \tau_{v,k-1}))\}$$

$$LogL = \sum_{v=1}^{n}\{R_{v1}(\alpha_1 - x'\beta - g'\lambda_j) - log(1+\exp(\alpha_1 - x'\beta - g'\lambda_j)) + (R_{v2} - R_{v1})(-x'\beta + \log(\exp(\alpha_2) - \exp(\alpha_1)) - log(1+\exp(\alpha_2 - x'\beta - g'\lambda_j)) - log(1+\exp(\alpha_1 - x'\beta - g'\lambda_j)) + +(R_{v3} - R_{v2})(-x'\beta + \log(\exp(\alpha_3) - \exp(\alpha_2)) - log(1+\exp(\alpha_3 - x'\beta - g'\lambda_j)) - log(1+\exp(\alpha_2 - x'\beta - g'\lambda_j)) + \cdots - (1 - R_{v,k-1})log\,((1+\exp(\alpha_{k-1} - x'\beta - g'\lambda_j)))\} \ldots\ldots\ldots\ldots (3.18)$$

By evaluating second order partial derivatives to minimize the function we get the estimators of the covariance matrix of the estimated coefficients.

3.5 Bayesian Inference for Ordinal Response Data:

The Bayesian approach which takes prior information about the parameters that are being studied in the particular model when we get prior information about the relevant parameters we merged it with the information that data provide.

3.5.1 Role of the Prior Distribution:

Prior distribution to the statistical analysis is the important aspect of the Bayesian approach. Different choices of prior will give different results so choice should be given careful thought joining a prior distribution with the likelihood function to attain a posterior distribution is called Bayesian because it is based on applying Bayes' theorem.

3.5.2 Simulating the Posterior Distribution:

Some time there is no close form of the posterior distribution therefore by simulation method we can approximate the posterior distribution. To obtain posterior distribution Markov chain Monte Carlo (MCMC) method is used, the process starts by choosing initial estimates for the parameters and using a "burn-in period" for the Markov chain until its probability distribution is close to the stationary distribution.

3.5.3 Prior Construction for Model:

In our model parameter σ^2 does not have any simple family of conjugate prior distributions the value of this parameter we take through hierarachical prior, by using a hierarchical approach in which those hyper parameters have their own prior distribution. Which is used in the common way for the Bayesian the analysis may then be more robust, with the subjectivity reduced because posterior results are averaged over a family of prior distributions the parameter σ^2 in model does not have any simple family of conjugate prior distributions because its marginal likelihood depends in a complex way on the data from all J groups (Hill, 1965, Tiao and Tan, 1965). However, the inverse-gamma family is conditionally conjugate.

When it is unclear how to select a prior distribution in a Bayesian analysis, it is sensible to specify the prior with a hierarchical structure, because the tail behavior of the prior has a large impact on robustness and parameter shrinkage (Polson and Scott 2010). The value of hierarchical prior parameters is estimated by elicitation of inverse-gamma distribution. as the value for our estimated model paramcters with normal prior and further hyperparameters σ^2 has own prior for hyperparamters we can either choose from the past study or calculate them by elicitation of that paramcters.

3.5.4 Bayesian Ordinal Logistic Regression:

The ordinal logistic regression model can be written in terms of a latent response variable lij as follows

$$l = \beta X_1 + bX_2 + \epsilon \text{..........................(3.19)}$$

here L is called "liabilities", $\epsilon \sim$ L(0,1) where L(.) denotes the logistic distribution, and the vector X_1 are explanatory variables associated with the fixed effects β and X_2 vector of explanatory variables associated with random effect b.

Since L is unobservable and can be measured indirectly by an observable ordinal variable Y , then L can be defined as given in Equation (3.3).

It is assumed here that the error term of the latent variable l is distributed as L (0,1) the cumulative response probability for the c category of the ordinal outcome y_{ij} is

$$P(y_{ij} \le c/\beta, b) = \pi_{ij}(c) = P(l_{ij} \le c/\beta, b) = P(\beta X_1 + bX_2 + \varepsilon_{ij} \le \gamma_c)$$

$$P(\varepsilon_{ij} \le \gamma_c - \beta X_1 - bX_2), \text{ for } c = 1,2,3 \ldots\ldots, c-1,$$

$$\pi_{ij}(c) = \frac{\exp((\gamma_c - \beta X_1 - bx_2)}{1+\exp((\gamma_c - \beta X_1 - bx_2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.20)}$$

Similarly Equation 3.19 can be written as a cumulative logit model

$$\log\left[\frac{\pi_{ij_{(c)}}(x)}{1-\pi_{ij_{(c)}}(x)}\right] = \gamma_c - \beta X_1 - bx_2, \text{ for } c = 1,2,3 \ldots\ldots, c-1,$$

$$P(y_{ij} = c/\beta, b) = \pi_{ij}(c)$$

$$\pi_{ij}(c) = p(\gamma_{ij(c-1)} < l_{ij} < \gamma_{ij(c)})$$

Since we have latent variables l_{ij} distributed as $L(\beta X_1 + bX_2, 1)$ we observe that $P(y_{ij} = c)$ if and only if $P(\gamma_{ij(c-1)} < l_{ij} < \gamma_{ij(c)})$ then the joint posterior density of the parameter vector and latent variable becomes

$$p(\beta, \gamma, b, \sigma_\beta^2, \sigma_b^2, l/y) \propto P(y/l, \gamma)(l/\beta, b)\, p(\gamma) \times P(b/\sigma^2_b)\, P(\beta/\sigma^2_\beta)\, p(\sigma_\beta^2), p(\sigma_b^2)$$

Let's assume that a normal prior distribution for fixed parameters $\beta \sim N(0, \Sigma_0\sigma^2_b)$ and also normal prior for random parameters $b_i \sim N(0, \sigma^2_b)$ or $b \sim N(0, G\sigma^2_b)$ further inverse-gamma (α_b, β_b) prior for "σ^2_b" and inverse-gamma $(\alpha_\beta, \beta_\beta)$ prior for "σ^2_β". The prior for the C− 1unknown thresholds has been given as order statistics from $U(\gamma_{min}, \gamma_{max})$ distribution.

$$P(\gamma) = (C-1)!\left(\frac{1}{\gamma_{min} - \gamma_{max}}\right)^{C-1} (\gamma \in T)$$

where $T = \{(\gamma_1, \gamma_2, \ldots, \gamma_{max})/\gamma_{min} < \gamma_{(1)} \ldots < \gamma_{C-1} < \gamma_{max}\}$

Liabilities and Pólya-Gamma Values:

The fully conditional posterior distribution of liability l_{ij} is

$$P\,(l/\text{data}) = P\,(l\,/\,\beta, b)\; P(y/l, \gamma)$$

$$\propto \prod_{i=1}^{I}\prod_{j=1}^{J} f(l_{ij}) \sum_{c=1}^{C}(y_{ij} = c)\; I(\gamma_{ij(c-1)} < l_{ij} < \gamma_{ij(c)})$$

$$\propto \prod_{i=1}^{I}\prod_{j=1}^{J} \frac{(\exp\,(-l_{ij}+\beta X_1+bX_2)}{[1+\exp\,(-l_{ij}+\beta X_1+bX_2)]^2} \sum_{c=1}^{C}(y_{ij} = c)\; I(\gamma_{ij(c-1)} < l_{ij} < \gamma_{ij(c)})$$

$$\propto \prod_{i=1}^{I}\prod_{j=1}^{J} 2^{-2} \int_0^{\infty} exp\,[\frac{-w_{ij}(-l_{ij} + \beta X_1 + bX_2)^2}{2}] \times$$

$$P(w_{ij};b=2,d=0)dw_{ij} \sum_{c=1}^{C}(y_{ij} = c)\; I(\gamma_{ij(c-1)} < l_{ij} < \gamma_{ij(c)})$$

Pólya-Gamma method (Scott and Pillow, 2013) was applied to obtain last inequality, which is useful when working with logistic likelihoods, and has the form

$$\frac{(e^{\rho})^{a}}{(1+e^{\rho})^{b}} = 2^{-b}e^{k\rho} \int_0^{\infty} e^{\frac{-w\rho^2}{2}} P(w;b,0)dw$$

where $k = \frac{a-b}{2}$ and P (w; b, 0) d w denote the density of the random variable

w ~ PG (b, d=0) where PG (b, d) denotes the Polygamma distribution

With parameter, d and density

$$P(w,b,d) = \{\cosh^{b}(\frac{d}{2})\}\frac{2^{b-1}}{\Gamma_b} \sum_{0}^{\infty}(-1)^{n} \frac{\Gamma_{(n+b)(2n+b)}}{\Gamma_{(n+1)}\Gamma_{2\pi w^3}} \exp(\frac{-(2n+b)^2}{8w} - \frac{d^2}{2}\, w)$$

where *cosh* denotes the hyperbolic cosine.

Then the joint distribution of l_{ij} and w_{ij} is equal to

$$P(l_{ij}, w_{ij}/\text{data}) \propto \prod_{i=1}^{I}\prod_{j=1}^{J} 2^{-2} \int_0^{\infty} exp\,[\frac{-w_{ij}(-l_{ij}+\beta X_1+bX_2)^2}{2}]$$

$$P(w_{ij};2,0) \sum_{c=1}^{C} I(y_{ij=c})\ I(\gamma_{ij(c-1)} < l_{ij} < \gamma_{ij(c)}) \text{.....................(3.21)}$$

As if $X \sim N(\mu, \sigma^2)$ has a normal distribution and lies within the interval $X \in (a, b), -\infty \leq a < b \leq +\infty$. Then $X\ a < X < b$ conditional has a truncated normal distribution. And probability density function f,for $a < X < b$ is

$$f(\mu, \sigma^2, a, b) = \frac{\emptyset(\frac{x-\mu}{\sigma})}{\sigma\left(\emptyset(\frac{b-\mu}{\sigma}) - \emptyset(\frac{a-\mu}{\sigma})\right)}$$

So Fully conditional posterior distribution from Equation (3.21) of liability l_{ij} is a truncated normal distribution and its density is

$$P(\ l_{ij}/\text{data}) = \frac{\emptyset(\beta X_1+bX_2,\ ^1/_{\sqrt{w_{ij}}})}{\emptyset(\gamma_c-\beta X_1^t-bX_2^t)-\emptyset(\gamma_{c-1}-\beta X_1^t-bX_2^t b)} \qquad \text{................(3.22)}$$

where $\emptyset(.)$ is the normal density including parameters as is indicated in the argument and $\emptyset$ is the CDF of a normal density with mean $\beta X_1 + bX_2$, and variance $^1/_{\sqrt{w_{ij}}}$. and the fully conditional posterior distribution of w_{ij} is

$$P(w_{ij}/\text{data}) \propto 2^{-2} exp\,[\frac{-w_{ij}(-l_{ij}+\beta X_1+bX_2)^2}{2}] P(w_{ij};2,0)$$

$$\propto exp\,[\frac{-w_{ij}(-l_{ij}+\beta X_1+bX_2)^2}{2}] P(w_{ij};2,0)$$

and from Polson *et al.,* (2013) Equation (5) we get that

$$P(w_{ij}/\text{data}) \sim PG(2,\ -l_{ij} + \beta X_1 + bX_2)$$

First note that the fully conditional posterior of l, β, w is

$$P(l, w, \beta/\text{data}) = P(l/\beta, b)\, P(y/l, \gamma) P(w) P(\beta/\sigma_\beta^2)$$

$$\propto exp\,(-\frac{1}{2}(-l+\beta X_1 + bX_2)^t D_w(-l + \beta X_1 + bX_2)\; P(w)P(\beta/\sigma_\beta^2)$$

$$\text{Where } P(w) = \prod_{i=1}^{n}\prod_{j=1}^{m} P(w_{ij}; 2{,}0)$$

Regression Coefficient(β):

Now fully conditional posterior distribution of β is

$$P(\beta/\text{data}) \propto exp\,(-\frac{1}{2}(-l+\beta X_1 + bX_2)^t D_w(-l + \beta X_1 + bX_2) - \frac{1}{2}(\beta - \beta_0)^t(\Sigma^{-1}\sigma_\beta^{-2})\,(\beta - \beta_0)$$

$$\propto exp\,(-\frac{1}{2}[\beta^t\Sigma_0^{-1}\sigma_\beta^{-2}\,\beta + \beta^t X_1^t D_w X_1\beta - \Sigma_0^{-1}\sigma_\beta^{-2}\beta_0 - \Sigma_0^{-1}\sigma_\beta^{-2}\beta_0 + X_1^t D_w X_2 + X_1^t D_w X_2 - X_1^t D_w l - X_1^t D_w l)^t)\beta])$$

$$\propto exp\,(-\frac{1}{2}[\beta^t(\Sigma_0^{-1}\sigma_\beta^{-2} + X_1^t D_w X_1)\beta - 2(\Sigma_0^{-1}\sigma_\beta^{-2}\beta_0 - X_1^t D_w X_2 + X_1^t D_w l)^t)\beta])$$

$$\propto exp\,(-\frac{1}{2}[\beta - \tilde{\beta}_0)^t)\tilde{\Sigma}_0^{-1}(\beta - \tilde{\beta}_0)$$

$$\text{where } \tilde{\Sigma}_0^{-1} = (\Sigma_0^{-1}\sigma_\beta^{-2} + X_1^t D_w X_1)^{-1},\; \tilde{\beta}_0 = (\Sigma_0^{-1}\sigma_\beta^{-2}\beta_0 - X_1^t D_w X_2 + X_1^t D_w l)$$

Here $D_w = diag\,(D_{w1}\ldots\ldots\ldots\ldots D_{wl})$, $D_{wl} = diag\,(w_{i1}\ldots\ldots\ldots w_{in})$

It is point to be noted that if we use a prior for $\beta \propto$ Constant (improper uniform distribution) then in $\tilde{\Sigma}_0$ and $\tilde{\beta}_0$ we need to make 0 the term $\Sigma_0^{-1}\sigma_\beta^{-2}$

So fully conditional posterior distribution of β is

$$P(\beta/data) = N_P(\tilde{\beta}_0, \tilde{\Sigma}_0^{-1}) \quad \ldots\ldots\ldots\ldots\ldots\ldots (3.23)$$

Regression Coefficient(b):

Now conditional posterior for b is

$$P(b/data) \propto \; exp\,(-\frac{1}{2}(-l+\beta X_1 + bX_2)^t D_w(-l + \beta X_1 + bX_2)\; P(b/\sigma_b^2)$$

$$\propto \; exp\,\{b^t(\sigma_b^{-2}G^{-1}+X_2^t D_w X_2)b - 2(X_2^t D_w l - X_2^t D_w X_2\; \beta X_1)^t b]\}$$

$$\propto \exp\{-\frac{1}{2}[\,(b-\breve{b})^t)F^{-1}\,(b-\breve{b})\}$$

where $\breve{b} = F(X_2^t D_w l - X_2^t D_w X_2\; \beta X_1)$ and $F=(\sigma_b^{-2}G^{-1} + X_2^t D_w X_2)^{-1}$

So fully conditional posterior distribution of b is

$$P(b/data) = N_P(\breve{b}, F) \quad \text{.............(3.24)}$$

Now conditional posterior distribution for σ_β^2:

where prior for σ_β^2 ~ inverse-gamma $(\alpha_\beta, \beta_\beta)$

$$P(\sigma_\beta^2/data) \propto \;(l(\beta)\; P(\sigma_\beta^2)$$

$$P(\sigma_\beta^2/data) \propto \frac{1}{(\sigma_\beta^2)^{\frac{k}{2}}}\, exp\,(-\frac{(X_1-U_1)^T\Sigma_0{}^{-1}(X_1-U_1)}{2\sigma_\beta^2}) \times \sigma_\beta^{2\,(-\alpha_\beta-1)} exp\,(\frac{\beta_\beta}{\sigma_\beta^2})$$

$$P(\sigma_\beta^2/data) \propto \;(\frac{1}{\sigma^2})^{\frac{k}{2}+\alpha_\beta+1}\, exp\,(\frac{(X_1-U_1)^T\Sigma_0{}^{-1}(X_1-U_1)+2\beta_\beta)}{2\sigma_\beta^2}$$

$P(\sigma_\beta^2/data)$ ~ inverse-gamma (α^*, β^*)

where $\alpha^* = \frac{k}{2} + \alpha_\beta$ and $\beta^* = \frac{(X_1-U_1)^T\Sigma_0{}^{-1}(X_1-U_1)+2\beta_\beta}{2}$

Now Conditional distribution for σ_b^2:

where prior of σ_b^2~ inverse-gamma (α_b, β_b)

$$P(\sigma_b^2/\text{data}) \propto (l(b)\, P(\sigma_b^2)$$

$$P(\sigma_b^2/\text{data}) \propto \frac{1}{(\sigma_b^2)^{\frac{k}{2}}} exp\,(-\frac{(X_2-U_2)^T G^{-1}(X_2-U_2)}{2\sigma_b^2}) \times \sigma_b^{2^{(-\alpha_b-1)}} \exp\,(\frac{\beta_b}{\sigma_b^2})$$

$$P(\sigma_b^2/\text{data}) \propto (\frac{1}{\sigma^2})^{\frac{k}{2}+\alpha_b+1} exp(\frac{(X_2-U_2)^T G^{-1}(X_2-U_2)+2\beta_b)}{2\sigma^2}$$

$P(\sigma_b^2/\text{data})$ ~ inverse-gamma (α', β') ....(3.25)

where $\alpha' = \frac{k}{2} + \alpha_b$ and $\beta' = \frac{(X_2-U_2)^T G^{-1}(X_2-U_2)+2\beta_b)}{2}$

Conditional posterior distribution for threshold (γ):

$$`P\ (\gamma/\text{data}) = P\ (y\ /\ l, \gamma)\ P\ (\gamma)$$

$$\propto \prod_{i=1}^{i} \prod_{j=1}^{j} \sum_{c=1}^{C} I(y_{ij=c})\ I\ (\gamma_{ij(c-1)} < l_{ij} < \ \gamma_{ij(c)})(\gamma \in T) \qquad \text{(a.1)}$$

If Equation (a.1) is function of c so it is clear that value of c must be larger than all the $l_{ij}/y_{ij} = c$ and smaller than all the $l_{ij}/y_{ij} = c + 1$. Hence, as a function of γ_c, Equation (a.1) leads to the uniform density

$$P(\gamma/\text{data}) = \frac{1}{\min(l_{ij}/y_{ij}=c+1) - \max\,(l_{ij}/y_{ij}=c)} \quad (\gamma \in T) \qquad \text{(a.2)}$$

Equation (a.2) corresponds to a uniform distribution on the interval $\min(l_{ij}/y_{ij} = c + 1)$ and max $(l_{ij}/y_{ij} = c$ (Albert and Chib 1993; Sorensen *et al,*. 1995).

3.6 Conclusion:

Data and methodology are discussed in this chapter. Some micro econometric indicator variables are calculated to study the food security in Pakistan. A suitable food security index is used to measure food security level that is called average per capita daily kilo calories. After construction of required variables, ordinal logistic technique is employed in classical frame work with various categories of ordinal logistic also Bayesian ordinal logistic is used in Bayesian frame work. To check the better performance of the classical frame work and Bayesian frame work results are to be discussed in next chapter.

Chapter 4

RESULTS AND DISCUSSIONS

4.1 Introduction:

This chapter presents results of the study related to food security, to measure food security in Pakistan we took different socio –economic and demographic variables, which play an important role in food security and these variables, are selected from the data set of PSLM 2013-14. Accordingly, the analysis is carried out in three sections. In first section the classical ordered logistics results are interpreted properly and the second section Bayesian ordinal logistic regression with informative and non-informative priors is discussed and last 3rd section contains comparison of classical ordinal logistic parameters and Bayesian parameters estimation.

4.2 Selection of Models in Classical Frame Work:

Our dependent variable is ordinal we use cumulative logit models to measure ordinal dependent variable. Cumulative logit models are further divided in 3 groups under the parallel line assumptions which are proportional odds model, non-proportional odds model and partial proportional odds model as cumulative logit models do work under the assumption of cumulative logit parallellity but parallel lines assumption sometimes does not hold; in this case proportional odds model gives inaccurate results. Therefore we use models that reflect on ordinal structure and relax the assumption are recommended. NPOM and PPOM are recently used for this purpose so first we will run proportional odds model if parallel line assumption meet then we will interpret its coefficients in odd ratio if parallel line doesn't meet then interpretation in odd ratio of proportional odds model will give inaccurate results then we have to move for non-proportional odds models or partial proportional odds models. Models selection and parallel line assumptions are tested as fallow,

4.2.1 Results of Proportional Odds Model:

Table 4.1. Coefficients, standard errors and p values of the Proportional Odds Model

	y	$Coef.$	$Std.Err.$	Z	$P>\|z\|$	[95% $Conf.Interval$]	
1	X_1	.6450	.0641	10.06	0.000	.5194	.7707
	X_2	2.4762	.0833	29.69	0.000	2.3127	2.6396
	X_3	-.3924	.0113	-34.64	0.000	-.4146	-.3702
	X_4	.8155	.0367	22.17	0.000	.74346	.8876
	X_5	.7855	.0510	15.38	0.000	.68545	.8856
	X_6	.0221	.0035	10.66	0.029	.01363	.0279
	X_7	-.0131	.0012	10.29	0.000	-.0156	-.0107
	X_8	-.6586	.0692	-9.51	0.000	-.7943	-.5228
	X_9	.0231	.0126	2.20	0.028	.00302	.0524
	X_{10}	.8816	.0450	19.62	0.000	.79655	.9733
	X_{11}	- .4436	.1084	-4.09	0.000	-.6559	-.2308
	X_{12}	.1416	.0048	29.95	0.000	.13476	.1536
	d_2	.2735	.0620	3.85	0.000	.11736	.3605
	d_3	-.2868	.0422	-5.09	0.000	-.2976	-.1321
	d_4	.0981	.0422	0.71	0.480	-.0567	.1207
	$cut1$	10.0731	.3805			9.3212	10.8183
	$cut2$	11.7254	.3833			10.9740	12.4768
	$cut3$	12.9567	.3857			12.2006	13.7128
	LR chi(15)	6764.05			0.000		
	Log likelihood	-19125.7					
	Pseudo R^2	0.1503					

4.2.2 Brant test for parallel line assumption:

Table 4.2 Brant test of parallel regression assumption

	$Chi2$	$p > chi2$	$d.f$
All	143.39	0.000	30
X_1	9.88	0.007	2
X_2	12.10	0.002	2
X_3	72.25	0.000	2
X_4	4.52	0.104	2
X_5	3.66	0.160	2
X_6	1.37	0.503	2
X_7	14.31	0.001	2
X_8	2.24	0.326	2
X_9	3.37	0.185	2
X_{10}	2.54	0.281	2
X_{11}	0.98	0.612	2
X_{12}	2.22	0.000	2
d_2	10.84	0.004	2
d_3	2.35	0.309	2
d_4	0.76	0.685	2

As it is given above in Table (4.2) that significant test statistic provides evidence that the parallel regression assumption has been violated. Brant test suggests that $X_1, X_2, X_3, X_7, X_{12}$ and d_2 violate the parallel lines assumption. Other variables do not appear to violate the assumption. So when parallel lines assumption violates then interpretation of logistic is not valid in term of odd ratios we have to move for another appropriate model.

4.2.3 Results of the Constrained Partial Proportional Odds Model:

Table 4.3 Coefficients, standard errors and p values of the Constrained Partial Proportional Odds Model.

	y	$Coef.$	$Std.Err.$	Z	$P > \|z\|$	[95% $Conf.Interval$]	
1	X_1	.6450	.0641	10.06	0.000	.5194	.7707
	X_2	2.4762	.0833	29.69	0.000	2.3127	2.6396
	X_3	-.3924	.0113	-34.64	0.000	-.4146	-.3702
	X_4	.8155	.0367	22.17	0.000	.74346	.8876
	X_5	.7855	.0510	15.38	0.000	.68545	.8856
	X_6	.0221	.0335	10.66	0.029	.04363	.0879
	X_7	-.0131	.0012	10.29	0.000	-.0156	-.0107
	X_8	-.6586	.0692	-9.51	0.000	-.7943	-.5228
	X_9	.0231	.0126	2.20	0.028	.00302	.0524
	X_{10}	.8816	.0450	19.62	0.000	.79655	.9733
	X_{11}	- .4436	.1084	-4.09	0.000	-.6559	-.2308
	X_{12}	.1416	.0048	29.95	0.000	.13476	.1536
	d_2	.2735	.0620	3.85	0.000	.11736	.3605
	d_3	-.2868	.0422	-5.09	0.000	-.2976	-.1321
	d_4	.0981	.0422	0.71	0.480	-.0567	.1207
	$cons$	-10.0731	.3805	-26.74	0.000	-10.8189	-9.3272
2	X_1	.6450	.0641	10.06	0.000	.5194	.7707
	X_2	2.4762	.0833	29.69	0.000	2.3127	2.6396
	X_3	-.3924	.0113	-34.64	0.000	-.4146	-.3702
	X_4	.8155	.0367	22.17	0.000	.74346	.8876
	X_5	.7855	.0510	15.38	0.000	.68545	.8856
	X_6	.0221	.0335	10.66	0.029	.04363	.0879
	X_7	-.0131	.0012	10.29	0.000	-.0156	-.0107
	X_8	-.6586	.0692	-9.51	0.000	-.7943	-.5228
	X_9	.0231	.0126	2.20	0.028	.00302	.0524
	X_{10}	.8816	.0450	19.62	0.000	.79655	.9733
	X_{11}	-.4436	.1084	-4.09	0.000	-.6559	-.2308
	X_{12}	.1416	.0048	29.95	0.000	.13476	.1536
	d_2	.2735	.0620	3.85	0.000	.11736	.3605
	d_3	-.2868	.0422	-5.09	0.000	-.2976	-.1321
	d_4	.0981	.0422	0.71	0.480	-.0567	.1207
	$cons$	-11.7254	.3833	-30.74	0.000	-12.4768	-10.9740
3	X_1	.6450	.0641	10.06	0.000	.5194	.7707
	X_2	2.4762	.0833	29.69	0.000	2.3127	2.6396
	X_3	-.3924	.0113	-34.64	0.000	-.4146	-.3702
	X_4	.8155	.0367	22.17	0.000	.74346	.8876
	X_5	.7855	.0510	15.38	0.000	.68545	.8856
	X_6	.0221	.0335	10.66	0.029	.04363	.0879
	X_7	-.0131	.0012	10.29	0.000	-.0156	-.0107

	X_8	-.6586	.0692	-9.51	0.000	-.7943	-.5228
	X_9	.0231	.0126	2.20	0.028	.00302	.0524
	X_{10}	.8816	.0450	19.62	0.000	.79655	.9733
	X_{11}	-.4436	.1084	-4.09	0.000	-.6559	-.2308
	X_{12}	.1416	.0048	29.95	0.000	.13476	.1536
	d_2	.2735	.0620	3.85	0.000	.11736	.3605
	d_3	-.2868	.0422	-5.09	0.000	-.2976	-.1321
	d_4	.0981	.0422	0.71	0.480	-.0567	.1207
	cons	-12.9567	.3857	-33.59	0.000	-13.7128	-12.2006
	LR chi(45)	6764.05			0.000		
	Log likelihood	-19125.7					
	Pseudo R^2	0.1503					

In above Table (4.3) there is striking the parallel lines assumption, the same parameter estimates show multiple times, as the effects are constrained to be equal for each cut-point . on the basis of above results we can say that, even tbough the proportional odd model and constrained partial proportional model give similar results when we constraint the parameters to meet parallel line assumption in each category of the dependent variable now, we'll estimate a model in which no variables have to meet the parallel lines assumption.

4.2.4 Results of the Unconstrained Partial Proportional Odds Model:

Table 4.4 Coefficients, standard errors and p values of the unconstrained Partial Proportional Odds Model.

	y	$Coef.$	$Std.Err.$	Z	$P > \|z\|$	[95% $Conf.Interval$]	
1	X_1	.5744	.0898	6.39	0.000	.3983	.7504
	X_2	2.2835	.1078	21.17	0.000	2.0721	2.494
	X_3	-.3502	.0142	-24.54	0.000	-.3782	-.3222
	X_4	.7949	.0465	17.17	0.000	.7037	.8861
	X_5	.8914	.0749	11.38	0.000	.7445	1.038
	X_6	.0664	.0235	11.66	0.015	.0184	.1114
	X_7	.0171	.0072	10.09	0.000	.0207	.0133
	X_8	-.6373	.0652	-6.51	0.000	-.8250	-.4492
	X_9	.0236	.0136	1.49	0.138	-.0075	.0547
	X_{10}	.8838	.0460	13.08	0.000	.7513	1.016
	X_{11}	-.3554	.1094	-2.09	0.020	-.6565	-.0543
	X_{12}	.2283	.0038	29.95	0.000	.2148	.24181
	d_2	.2887	.0670	33.25	0.000	.1292	.4481
	d_3	-.2969	.0472	-5.33	0.000	-.4062	-.1872
	d_4	.0484	.0412	-0.88	0.415	-.1649	.0680
	$cons$	-9.9131	.5145	-19.74	0.000	-10.9389	-8.8954
2	X_1	.8336	.0793	10.26	0.000	.6776	.9897
	X_2	2.319	.1021	24.69	0.000	2.3081	2.7121
	X_3	-.4370	.0142	-29.64	0.000	-.4646	-.4002
	X_4	.7773	.0467	17.17	0.000	.68346	.8676
	X_5	.7404	.0610	12.38	0.000	.6154	.8656
	X_6	.0066	.0405	10.66	0.05	.07363	.0879
	X_7	-.0113	.0012	7.29	0.003	-.0146	-.0072
	X_8	-.5707	.0822	-6.51	0.000	-.7343	-.4228
	X_9	.0476	.0156	2.90	0.028	-.07902	0.578
	X_{10}	.8969	.0545	16.62	0.000	.7565	1 .0133
	X_{11}	-.4283	.1264	-4.09	0.000	-.6559	-.0508
	X_{12}	.0976	.0063	29.95	0.000	.21476	.2436
	d_2	.0774	.0761	3.85	0.300	.12736	.4405
	d_3	-.1742	.0511	-5.09	0.001	-.4076	-.1821
	d_4	.0596	.0541	0.71	0.277	-.1567	- .1207
	$cons$	-12.153	.4719	-25.74	0.000	-10.9189	-8.3272
3	X_1	.8950	.0891	10.06	0.000	.7207	1 .0707
	X_2	2.3662	.1208	29.69	0.000	2.3527	2.9096
	X_3	-.4724	.0113	-34.64	0.000	-.5146	-.4702
	X_4	.8755	.0547	22.17	0.000	.76346	.9876
	X_5	.6855	.0610	15.38	0.000	.55545	.8256
	X_6	.0062	.0435	10.66	0.029	.14363	.1879

	X_7	-.00831	.0012	10.29	0.000	-.0156	-.0107
	X_8	-.6986	.0992	-9.51	0.000	-.8643	-.5228
	X_9	.0651	.0260	2.20	0.013	.02302	.1524
	X_{10}	.8816	.0509	19.62	0.000	.79655	.9733
	X_{11}	-.5636	.1384	-4.09	0.000	-.6359	-.2308
	X_{12}	.06616	.0078	29.95	0.000	.0516	.1536
	d_2	.2835	.0620	3.85	0.000	.11736	.3605
	d_3	-.1368	.0632	-5.09	0.035	-.2976	-.1321
	d_4	.1081	.0622	0.71	0.123	-.0267	.2207
	$cons$	-13.0731	.5452	-26.74	0.000	-14.8189	-12.372
	LR chi(45)	7320.07			0.0000		
	Log likelihood	-18847.7					
	Pseudo R^2	0.1626					

From above Table (4.4) we observed that the estimates for X_1,, X_3,X_7,X_{12}, and d_2 they differ considerably across cut-points, while differences in the effects of other variables are rather small it is also noted that Brant test already given information about these variables which are problematic most for the parallel line assumption. Two model are fitted above in two figures in one we constrain the parameters to meet parallel line assumption and in second model in which no constraint for any parameters to meet parallel line assumptions results are given above and we can say on basis of these results that Brant test suggested for those variables they are creating problem for parallel line assumption because parameters values are varying through cut-points. Hence, we can now use the auto fit option to see whether a partial proportional odds model can fit the data. In a partial proportional odds model, some variables meet the proportional odds assumption while others do not.

4.2.5 Results of the Partial Proportional Odds Model:

Table 4.5 Coefficients, standard errors and p values of the PPOM.

1	y	$Coef.$	$Std.Err.$	Z	$P > \lvert z \rvert$	[95% $Conf.Interval$]	
	X_1	.5600	.0854	6.56	0.000	.3927	.7274
	X_2	2.4643	.0838	29.39	0.000	2.3000	2.6284
	X_3	-.3617	.0123	-29.21	0.000	-.3860	-.3374
	X_4	.8042	.0370	21.69	0.000	.7315	.8768
	X_5	.7719	.0511	15.08	0.000	.6716	.8723
	X_6	.0279	.0037	10.83	0.047	.0281	.0340
	X_7	.0179	.0016	10.91	0.000	.0217	.0141
	X_8	-.6307	.0689	-9.15	0.000	-.7659	-.4956
	X_9	.0397	.0128	3.10	0.002	.0146	.0648
	X_{10}	.8662	.0453	19.09	0.000	.7773	.9554
	X_{11}	-.4501	.1080	-4.16	0.000	-.6620	-.2383
	X_{12}	.2274	.0068	33.23	0.000	.2140	.2408
	d_2	.3210	.0763	4.21	0.000	.1714	.4706
	d_3	-.2118	.0424	-4.99	0.035	-.2952	-.1287
	d_4	.0259	.0455	0.57	0.563	.0633	.1151
	$cons$	-10.5332	.4411	-23.88	0.000	-11.4021	-9.6717
	X_1	.8659	.0768	11.27	0.000	.7153	1.0642
	X_2	2.4643	.0838	29.39	0.000	2.3000	2.6284
2	X_3	-.4328	.0127	-33.99	0.000	-.4560	-.4074
	X_4	.8042	.0370	21.69	0.000	.7315	.8768
	X_5	.7719	.0511	15.08	0.000	.6716	.8723
	X_6	.0279	.0037	10.83	0.047	.0281	.0340
	X_7	-.0111	.0015	7.35	0.000	-.0147	-.0081
	X_8	-.6307	.0689	-9.15	0.000	-.7659	-.4956
	X_9	.0397	.0128	3.10	0.002	.0146	.0648
	X_{10}	.8662	.0453	19.09	0.000	.7773	.9554
	X_{11}	-.4501	.1080	-4.16	0.000	-.6620	-.2383
	X_{12}	.0984	.0060	16.23	0.000	.0861	.1104
	d_2	.3580	.0725	0.80	0.000	.3514	.4006
	d_3	-.2118	.0424	-4.99	0.035	-.2952	-.1287
	d_4	.0259	.0455	0.57	0.563	.0633	.1151
	$cons$	-12.0009	.41443	-28.96	0.000	-12.8132	-11.1886
3	X_1	.8767	.0854	10.29	0.000	.7098	1.0437
	X_2	2.4643	.0838	29.39	0.000	2.3000	2.6284
	X_3	-.4588	.0123	-32.84	0.000	-.4862	-.4314
	X_4	.8042	.0370	21.69	0.000	.7315	.8768
	X_5	.7719	.0511	15.08	0.000	.6716	.8723
	X_6	.0279	.0337	4.83	0.047	.0281	.0340
	X_7	-.0076	.0016	10.91	0.000	-.0117	-.0021
	X_8	-.6307	.0689	-9.15	0.000	-.7659	-.4956

	X_9	.0397	.0128	3.10	0.002	.0146	.0648
	X_{10}	.8662	.0453	19.09	0.000	.7773	.9554
	X_{11}	-.4501	.1080	-4.16	0.000	-.6620	-.2383
	X_{12}	.0670	.0068	8.99	0.000	.0522	.0818
	d_2	.3887	.0763	2.88	0.000	.2358	.5411
	d_3	-.2118	.0424	-4.99	0.035	-.2952	-.1287
	d_4	.0259	.0455	0.57	0.563	.0633	.1151
	cons	-12.79724	.432658	-29.58	0.000	-13.6452	-11.9492
	LR chi(45)	7290.78			0.000		
	Log likelihood	-18847.7					
	Pseudo R^2	0.1620					
	Chi2(20)	29.16			0.0846		

Table 4.6 Odds Ratio for PPOM.

	$Y \leq 1\ VS. Y > 1$ OR	$Y \leq 2\ VS. Y > 2$ OR	$Y \leq 3\ VS. Y > 3$ OR
X_1	1.7506	2.3772	2.4030
X_2	11.7552	11.7552	11.7552
X_3	.6964	.6486	.6319
X_4	2.2349	2.2349	2.2349
X_5	2.1640	2.1640	2.1640
X_6	1.0283	1.0283	1.0283
X_7	1.0181	.9818	.9814
X_8	.5321	.5321	.5321
X_9	1.0405	1.0405	1.0405
X_{10}	2.3780	2.3780	2.3780
X_{11}	.6375	.6375	.6375
X_{12}	1.2554	1.1035	1.0694
d_2	1.3786	1.4032	1.4786
d_3	.8089	.8089	.8089
d_4	1.0262	1.0262	1.0262
cons	.00002	6.13869E-06	2.77E-06

These results in Table (4.5) show that 10 of the 15 variables that meet the parallel lines assumption which are $X_2, X_4, X_5, X_6, X_8, X_9, X_{10}, X_{11}, d_3, d_4$, while X_1, X_3, X_7, X_{12}, and d_2 do not meet the parallel assumption also in this table An insignificant test statistic indicates that the final model does not violate the proportional odds/ parallel lines assumption.

4.3 Selection of Model in Bayesian Frame Work.

As we have to compare Bayesian model with classical model we have seen in classical fame work that partial proportional give better results according to our study of ordinal variable so in Bayesian we have to run partial proportional odd model with informative prior and also with non informative prior to check its performance. The results of both models are given below as,

4.3.1 Bayesian Estimation with Non-Informative Prior:

Table 4.7 Coefficients, standard errors, MCSE, Median and 95% cred.interval values of the non informative normal prior.

1	y	$Mean$	$Std.Dev.$	$MCSE$	$Median$	[95% $Cred.Interval$	
	X_1	.6538	.0438	.0055	.6532	.5607	.7435
	X_2	2.4874	.0231	.0042	2.488	2.4492	2.545
	X_3	-.3933	.0098	.0005	-.3935	-.4126	-.3743
	X_4	.8001	.0314	.0012	.7943	.7375	.86237
	X_5	.8137	.0403	.0013	.8121	.7348	.8895
	X_6	.0162	.0303	.0061	.0167	-.0445	.0732
	X_7	.0132	.0012	.0019	.0132	.0107	.01566
	X_8	-.6654	.0594	.0004	-.6653	-.7835	-.5537
	X_9	.0284	.0114	.0001	.0265	.0062	.0509
	X_{10}	.9001	.0424	.0005	.8967	.8192	.9950
	X_{11}	-.5107	.0731	.0034	-.5132	-.6520	-.3656
	X_{12}	.1539	.0047	.0083	.1443	.1453	.1728
	d_2	.2570	.0488	.0013	.2523	.1672	.3604
	d_3	-.1912	.0327	.0028	-.1928	-.2537	-.1287
	d_4	.0648	.0289	.0004	.0634	.0169	.1253
	$cons$	-10.0140	.0456	.0064	-10.0931	-10.021	-9 .1231
2	X_1	.7047	.0412	.0059	.7032	.5812	.7231
	X_2	2.4874	.0231	.0042	2.488	2.4492	2.545
	X_3	-.4430	.0083	.0010	-.4435	-.4527	-.3743
	X_4	.8001	.0314	.0012	.7943	.7375	.86237
	X_5	.8137	.0403	.0013	.8121	.7348	.8895

	X_6	.0162	.0303	.0061	.0167	-.0445	.0732
	X_7	-.0232	.0023	.0020	- .0132	- .0107	-.01566
	X_8	-.6654	.0594	.0004	-.6653	-.7835	-.5537
	X_9	.0284	.0114	.0001	.0265	.0062	.0509
	X_{10}	.9001	.0424	.0005	.8967	.8192	.9950
	X_{11}	-.5107	.0731	.0034	-.5132	-.6520	-.3656
	X_{12}	.1036	.0039	.0088	.1143	.1011	.1629
	d_2	.2664	.0327	.0021	.2523	.2072	.3904
	d_3	-.1912	.0327	.0028	-.1928	-.2537	-.1287
	d_4	.0648	.0289	.0004	.0634	.0169	.1253
	cons	-11.0140	.0456	.0064	-11.0931	-12.021	-9 .1231
3	X_1	.7536	.0438	.0060	.7532	.6606	.8435
	X_2	2.4874	.0231	.0042	2.488	2.4492	2.545
	X_3	-.4832	.0098	.0015	-.4835	-.5026	-.4643
	X_4	.8001	.0314	.0012	.7943	.7375	.86237
	X_5	.8137	.0403	.0013	.8121	.7348	.8895
	X_6	.0162	.0303	.0061	.0167	-.0445	.0732
	X_7	-.0122	.0012	.0021	-.0132	- .0107	- .01566
	X_8	-.6654	.0594	.0004	-.6653	-.7835	-.5537
	X_9	.0284	.0114	.0001	.0265	.0062	.0509
	X_{10}	.9001	.0424	.0005	.8967	.8192	.9950
	X_{11}	-.5107	.0731	.0034	-.5132	-.6520	-.3656
	X_{12}	.0936	.0047	.0090	.1443	.0834	.1320
	d_2	.2772	.0488	.0015	.2723	.1972	.3004
	d_3	-.1912	.0327	.0028	-.1928	-.2537	-.1287
	d_4	.0648	.0289	.0004	.0634	.0169	.1253
	cons	-13.0121	.0456	.0064	-13.0931	-14.021	-11 .1231
	Log marginal likelihood	-19346.387					

Above in Table (4.7) model was estimated with non informative prior as our model contained two types of parameters first which full fill parallel line assumptions and second which do not full fill parallel line assumptions. Parameters of first kind have own prior and parameters of second kind have own prior. in non informative prior we recommend the high variance of the parameters and find the best results on given variance, so we have used normal non informative prior for model all parameters of 2 kinds fallow normal prior with mean 0 and variance 10^4 and results are given in above Table and also multiple diagnostic tests contain trace plot, histogram, autocorrelation and density for all parameters that are estimated in Table are given in appendix:B .

4.3.2 Bayesian Estimation with hierarchical Prior:

Table 4.8 Coefficients, standard errors, MCSE, Median and 95% cred.interval values of the hierarchical prior.

	y	$Mean$	$Std.Dev.$	$MCSE$	$Median$	[95% $Cred.Interval$	
1	X_1	.6256	.0157	.0013	.6249	.5958	.6568
	X_2	2.4833	.0140	.0011	2.4830	2.455	2.5103
	X_3	-.3928	.0078	.0006	-.3921	-.4082	-.3774
	X_4	.8135	.0279	.0018	.8130	.7577	.8670
	X_5	.7645	.0169	.0020	.7641	.7330	.7984
	X_6	.0270	.0045	.0011	.0265	.0219	.0446
	X_7	.0130	.0011	.0006	.0131	.0108	.0471
	X_8	-.6307	.0318	.0024	-.6301	-.6928	-.5674
	X_9	.0290	.0092	.0009	.0285	.0115	.0471
	X_{10}	.9020	.0247	.0016	.9013	.8527	.9506
	X_{11}	-.4323	.0205	.0018	-.4319	-.4721	-.3929
	X_{12}	.1438	.0042	.0003	.1435	.1360	.1526
	d_2	.2384	.0200	.0019	.2374	.1978	.2764
	d_3	-.1998	.0189	.0013	-.1935	-.2363	-.1615
	d_4	.0562	.0264	.0017	.0572	.0055	.1094
	$cons$	-10.5432	.0150	.0010	-10.5429	-11.4021	-9.6717
2	X_1	.6456	.0117	.0014	.6447	.6253	.6662
	X_2	2.4833	.0140	.0011	2.4830	2.455	2.5103
	X_3	-.4028	.0071	.0017	-.4023	-.4182	-.3874
	X_4	.8135	.0279	.0018	.8130	.7577	.8670
	X_5	.7645	.0169	.0020	.7641	.7330	.7984
	X_6	.0270	.0045	.0011	.0265	.0219	.0446
	X_7	-.0128	.0010	.0005	-.0127	-.0138	-.0111
	X_8	-.6307	.0318	.0024	-.6301	-.6928	-.5674
	X_9	.0290	.0092	.0009	.0285	.0115	.0471
	X_{10}	.9020	.0247	.0016	.9013	.8527	.9506
	X_{11}	-.4323	.0205	.0018	-.4319	-.4721	-.3929
	X_{12}	.1228	.0041	.0005	.1220	.1112	.1326
	d_2	.2681	.0199	.0021	.2574	.1978	.2764
	d_3	-.1998	.0189	.0013	-.1935	-.2363	-.1615
	d_4	.0562	.0264	.0017	.0572	.0055	.1094
	$cons$	-12.5432	.0150	.0010	-12.5422	-13.4021	-12.0012
3	X_1	.6859	.0157	.0017	.6849	.6514	.7167

	X_2	2.4833	.0140	.0011	2.4830	2.455	2.5103
	X_3	-.4528	.0078	.0011	-.4520	-.4682	-.4374
	X_4	.8135	.0279	.0018	.8130	.7577	.8670
	X_5	.7645	.0169	.0020	.7641	.7330	.7984
	X_6	.0270	.0045	.0011	.0265	.0219	.0446
	X_7	-.0135	.0011	.0013	-.0129	-.0192	- .0130
	X_8	-.6307	.0318	.0024	-.6301	-.6928	-.5674
	X_9	.0290	.0092	.0009	.0285	.0115	.0471
	X_{10}	.9020	.0247	.0016	.9013	.8527	.9506
	X_{11}	-.4323	.0205	.0018	-.4319	-.4721	-.3929
	X_{12}	.1012	.0042	.0012	.1009	.1001	.1126
	d_2	.2981	.0200	.0011	.2974	.2578	.2963
	d_3	-.1998	.0189	.0013	-.1935	-.2363	-.1615
	d_4	.0562	.0264	.0017	.0572	.0055	.1094
	$cons$	-13.5432	.0150	.0010	-13.5429	-14.4021	-13.002

Table 4.9 Odds Ratio for Bayesian PPOM.

	$Y \leq 1$ $VS. Y > 1$ OR	$Y \leq 2$ $VS. Y > 2$ OR	$Y \leq 3$ $VS. Y > 3$ OR
X_1	1.8693	1.9071	1.9855
X_2	11.9807	11.9807	11.9807
X_3	0.6753	0.6668	0.6358
X_4	2.2557	2.2557	2.2557
X_5	2.1479	2.1479	2.1479
X_6	1.0273	1.0273	1.0273
X_7	1.0137	0.9872	0.9865
X_8	0.5322	0.5322	0.5322
X_9	1.0294	1.0294	1.0294
X_{10}	2.4645	2.4645	2.4645
X_{11}	0.6490	0.6490	0.6490
X_{12}	1.1546	1.1306	1.1012
d_2	1.2692	1.3012	1.3492
d_3	0.8188	0.8188	0.8188
d_4	1.05780	1.05780	1.05780
$cons$	2.63722E-05	3.56722E-05	1.31722E-05

Table 4.10 Elicitation results for the parameters of inverse-gamma distribution.

Hyper Parameters	α	β
σ_1^2	1.5	2.5
σ_2^2	1.90	2.00
σ_3^2	1.35	1.95
σ_4^2	0.74	0.95
σ_5^2	2.12	2.45
σ_6^2	1.64	1.95
σ_7^2	1.85	2.05
σ_8^2	1.35	1.90
σ_9^2	0.90	0.98
σ_{10}^2	1.75	1.98
σ_{11}^2	1.74	1.94
σ_{12}^2	1.46	1.98
σ_{d2}^2	0.46	0.92
σ_{d3}^2	0.35	0.89
σ_{d4}^2	0.84	0.96

Our estimated model in Table (4.8) is Bayesian PPOM model with hierarchical prior where dependent variable has 4 categories and belongs from generalized linear family and expantory variables have 2 types of parameters, first kind of parameters which fullfil parallel line assumption and second which do not full fill that assumtion as we have seen in Table (4.3). Parameters of explantory vaiables which full fill parallel assumtion have normal prior with mean μ_β and variance σ_β^2 also parameters which do not full fill parallel line assumptions have prior with mean μ_b and variance σ_b^2 .

The value of hierarchical prior parameters is estimated by elicitation of inverse-gamma distribution. The elicitation is done for the selection of suitable value of the hyperparameters for estimated model parameters σ_β^2 and σ_b^2 . Our estimated model parameters with normal prior and further hyperparameters both σ_β^2 and σ_b^2 has own prior and their values are calculated by the elicitition given in Table (4.10). Also multiple diagnostic tests contain trace plot, histogram, autocorrelation and density for all parameters which fallow parallel line assumption and which do not that are estimated in Table (4.8) with hierarchical prior are given in figures 4.1 to 4.15 below. Hyper parameters σ_β^2 and σ_b^2 have own priors that is inverse gamma so both σ_β^2 and σ_b^2 will be treated as variable in the model and their estimates are given in appendix Table (4.8.1) and multiple diagnostic tests for hyper parameters are given in Appendix A.

Figure 4.1 Trace plot, histogram, autocorrelation and density for parameter of Log-income.

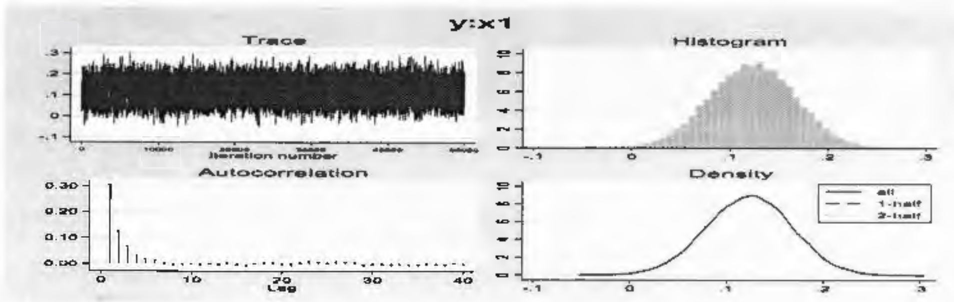


Figure 4.2 Trace plot, histogram, autocorrelation and density for parameter of Log-expenditure.

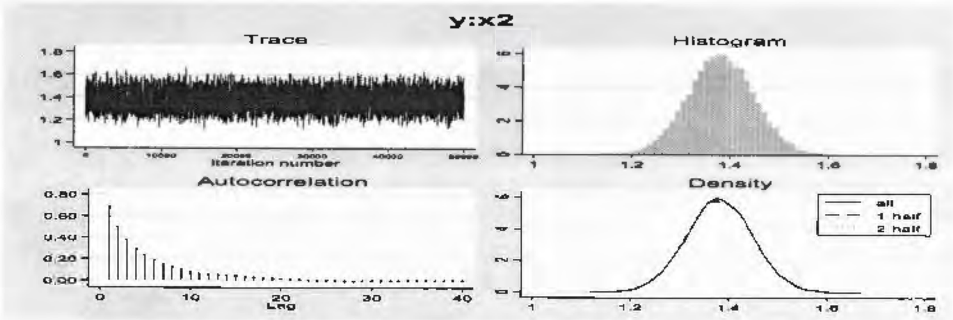


Figure 4.3 Trace plot, histogram, autocorrelation and density for parameter of Household's size.

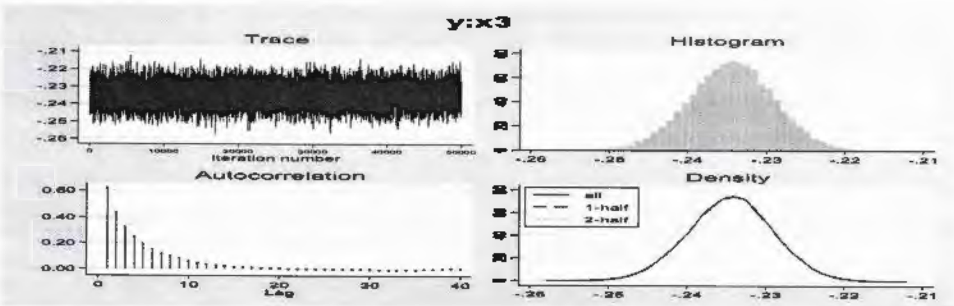


Figure 4.4 Trace plot, histogram, autocorrelation and density for parameter of Region.

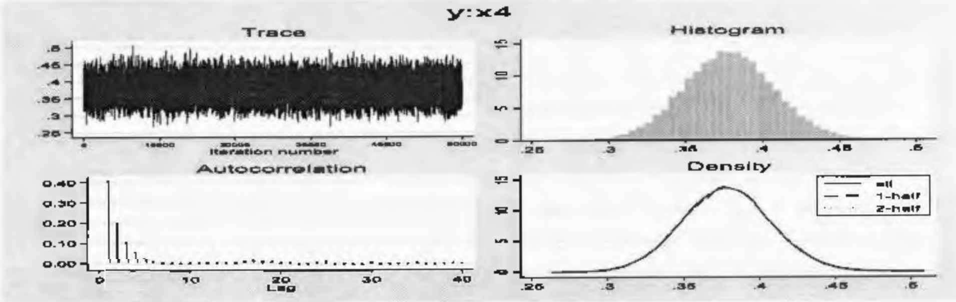


Figure 4.5 Trace plot, histogram, autocorrelation and density for parameter of live stock .

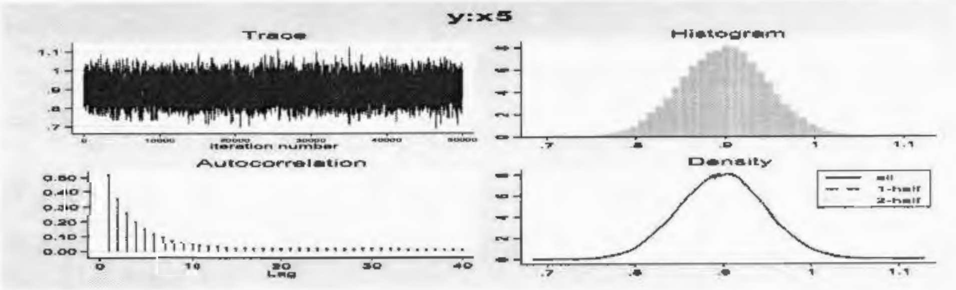


Figure 4.6 Trace plot, histogram, autocorrelation and density for parameter of Employment status .

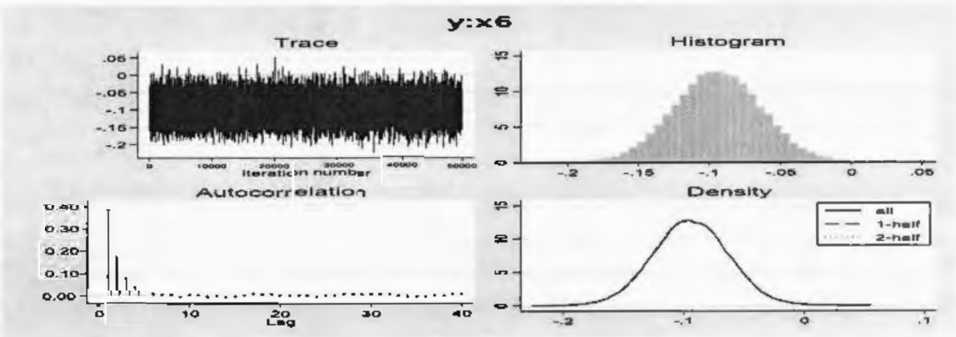


Figure 4.7 Trace plot, histogram, autocorrelation and density for parameter of Age of household's head.

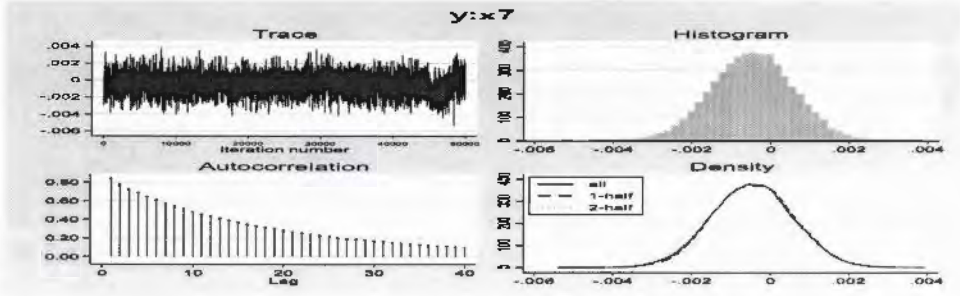


Figure 4.8 Trace plot, histogram, autocorrelation and density for parameter of Gender of household's head.

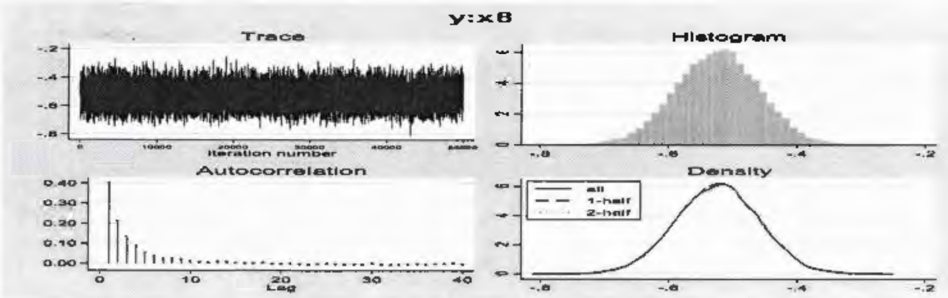


Figure 4.9 Trace plot, histogram, autocorrelation and density for parameter of no. of children with hierarchical prior .

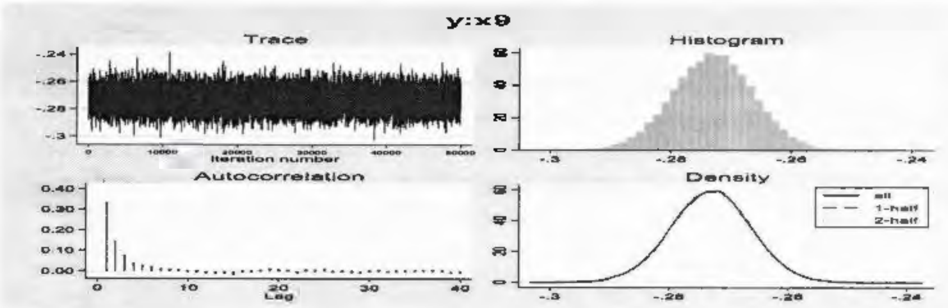


Figure 4.10 Trace plot, histogram, autocorrelation and density for parameter of Agriculture status.

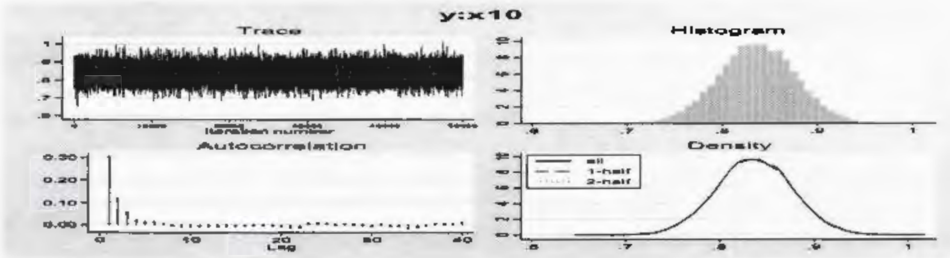


Figure 4.11 Trace plot, histogram, autocorrelation and density for parameter of Marital status.

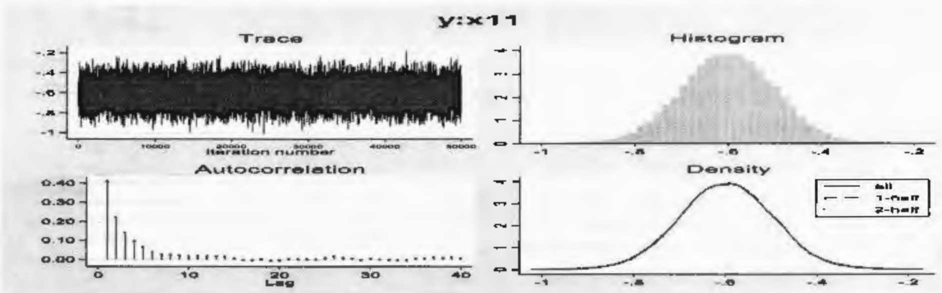


Figure 4.12 Trace plot, histogram, autocorrelation and density for parameter of Education.

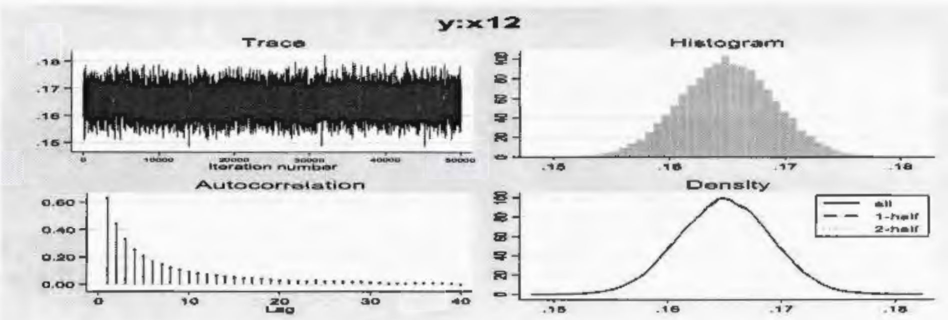


Figure 4.13 Trace plot, histogram, autocorrelation and density for parameter of Punjab.

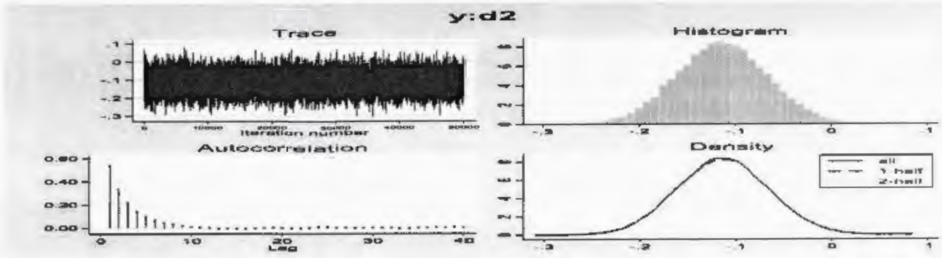


Figure 4.14 Trace plot, histogram, autocorrelation and density for parameter of Blochistan.

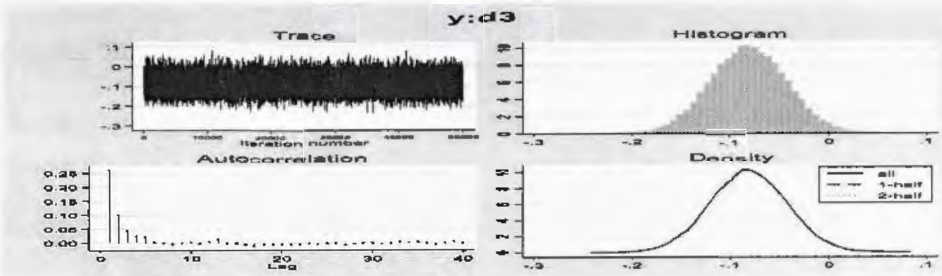


Figure 4.15 Trace plot, histogram, autocorrelation and density for parameter of Sindh.

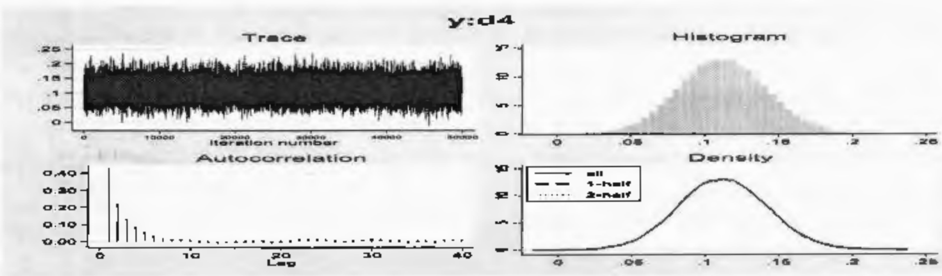


Figure 4.16 Trace plot, histogram, autocorrelation and density for Cut1.

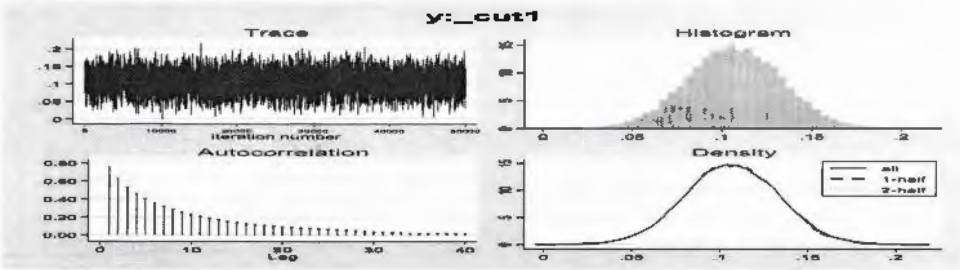


Figure 4.16 Trace plot, histogram, autocorrelation and density for Cut2.

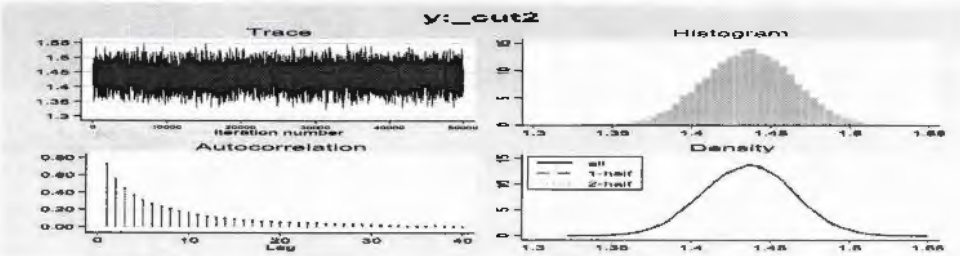
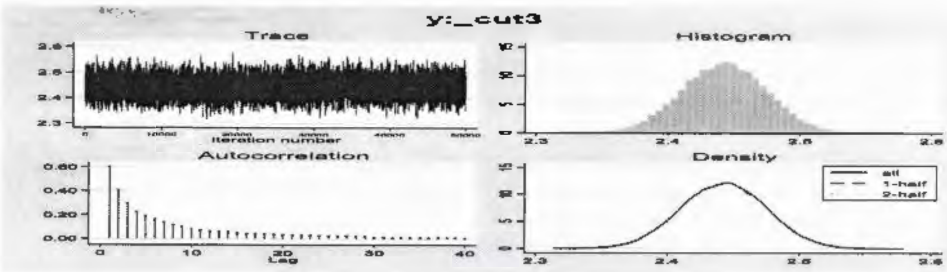


Figure 4.17 Trace plot, histogram, autocorrelation and density for Cut2.



4.4 Comparison:

We have estimated 3 models first model is classical PPOM second model is Bayesian PPOM with non-informative prior and model three is Bayesian PPOM with informative prior in Table (4.5), (4.7) and (4.8) successively. Results are clearly given in above 3 tables and we can see that which model has small variance and small confidence interval for the prediction. Model estimated in Table (4.8) which was estimated with normal informative prior has given small variance and small confidence interval as well. In cross sectional data analysis Bayesian and classical results are compared on the basis of variances and confidence intervals so estimated model with informative prior has better results than 2 other models. Bayesian has main advantage in its calculation that is prior information even our means values are not given by any weight but variances are given as weight through the prior information and results clearly shows that when we add prior information with sample information results are calculated in better than classical approach.

Interpretation of the all parameters of the Table (4.8) is slightly different from regular model that are estimated in logistic regression for binary or multi categorical dependent variables. In this estimation there are different cut-points and some of parameters which have different values across each cut-point. Also interpretation is different for parameters which don't fulfill parallel line assumption and they are varying across cut-points.

There are four categories of our dependent variable and three panels of estimates will be shown above and last panel will be considered as a reference panel of the model here interpretation of first panel of the estimates will be same as we do in binary regression model where dependent variable's categories are compared as

$1\ vs.\ 2+3+4$. Also second panel of estimates will be interpreted too as binary logit where dependent variable is recorded $as\ 1+2\ vs.\ 3\ and\ 4$. If parameters have positive coefficient it means it is expected to lie in currant or higher category and as well if it has negative sign means probable to fall in currant category or lower.

From the above we can see that positive sign of employment status (X_6) shows that household's heads that have job their families are secure as compare to those who don't have job also it is given in Table 4.9 that if a household's head has job its odds increases by 2.73% (OR=1.0273) to lie at or beyond the category, also in above table negative sign of marital status (X_{11}) shows that those household's heads are married their family status lies in insecure category as compare to household's heads those are unmarried also in Table (4.9) odds is -35.1% (OR=0.6490) that means less expected to lie in food secure category. It's also given gender (X_8) with negative sign shows that household's heads are male tend to be food insecure as compare to households their heads are women. Agriculture (X_{10}) with positive coefficient shows that those have own land or have agriculture facility their family lies in food secure category.

Log-Expenditure level (X_2) shows that families spend more are considered tend to be more food secures positive coefficients of Log-exp imply that with increase in its value, likelihood increases for housebolds to be more food secure with odds increases by 1098.07% to lie at or beyond the category. While other variables that fall in food secure category as families who have live stock (X_5) falling in food secure category as compare to family who doesn't have their live stock. Also no. of children (X_9) shows that households those have high ratio of children in their family fall in food secure category and families those live in urban areas fall in food secure category as compare to rural areas.

The coefficient of Log-income (X_1) is positive across cut-points and also it is continuously increase across cut-points that means Log-income implies that if increase its value households are expected to be in more food secure category, therefore high income of the heads of the households are expected to be more food secure than low income of households' heads, with the greatest differences being that households were hopeful to fall in medium and high category of food security also from Table (4.9) we can see the odds ratio to being at or beyond the category is as fallow, 1 vs 2+3+4 if one unit increases in income of the household increases the odds of getting secure category by 86.93% also 1+2 vs. 3+4 the odds increases 90.71% to fall at or beyond the categories and 1+2+3 vs. 4 odds of being or beyond the categories is 98.55% .

Also the coefficient of family size (X_3) effect is negative but gets larger across cut points. Hence, it tends to be food insecure, with the greatest differences being that households are unlikely to place themselves in the medium and high category of food security same pattern has shown in Table (4.9) for first panel of estimates odds -32.47% that means unlikely to put themselves in secure category also 1+2 vs 3+4 odds is -33.32% and 1+2+3 vs 4 odds is -0.3642% that means less likely put in high category.

For household head age (X_7), the pattern is more complicated. They are less likely to put themselves in a very low category (see the positive households' head age coefficient in the very low panel), but they are also less likely to put themselves in higher levels (see the negative household head age coefficients in the other panels).

The coefficients of education (X_{12}) show when one unit increase in a head education their family lies in food secure category the coefficients for (X_{12}) are consistently positive but decline across cut-points which means that educated households' heads lead to fall their family in food secure category across time, but the greatest effect of time they are less expected to stay in very low and low category of food security.

The coefficient of Baluchistan (d_3) shows that households living in Baluchistan are food insecure as compare to KPK. Conversely, (d_4) shows households are living in Sind consider food secure as compare to household who are living in KPK also the coefficients of (d_2) every time positive and gets large across cut points which shows that households having Punjab are more food secure than households of KPK with maximum disparities being that Punjab households are promising to fall in medium and high category.

4.5 Summary:

We have discussed classical frame work of the analysis and found partial proportional odd model is best model in classical frame work for also we used partial proportional odd model in Bayesian frame work and results have shown that Bayesian technique gives better results.

Chapter 5

SUMMARY AND CONCLUSION

The last chapter presents summary of the study. It concludes the study and presents policy implications and recommendations. In this study it is made an attempt to evaluate the food security level in Pakistan in order to understand the reason behind food insecurity in country.

In this study there are some possible factors that are being considered main factors that effect on the households' food security level in Pakistan. on the basis of our analysis food insecurity usually high among households' their income level is low, no proper source of agriculture sector, non-possession of livestock, low level of education, high level of dependency, male head, residence in rural region and also from the province of Baluchistan.

It divulges into the question of how to achieve sustainable food security at house hold level. The study of pattern of food security is important because it is not only shows past behavior of food insecurity level but also provides guidelines for further policies. Some factors are being identified by this study which may possibly contribute to improve and worsen the situation of household's food security.

The objective of present study is to analyze food security level at house hold level appropriate methodology is developed to carry out for the analysis. Data is carefully collected and analyzed. In this study average per capita daily kilo calories consumed index is used to measure food security level at house hold level, ordered logistic technique is used in classical work and Bayesian ordered logistic is also use to measure the significance effect of the variables.

Study reveals that Pakistan is not considered as a food secure country. Because Low income, lack of education, insufficient food, paucity of proper food to access to the market and common people. On the basis of the analysis of this study some suggestions are given as income and expenditure are most powerful and influencing factors to determine the households' food security in Pakistan and also theses variables are highly significant to measure food security level of households. Also education level is directly or indirectly affecting on the level of households food security. It is required attention about these factors to improve them and make Pakistan food secure country in the world.

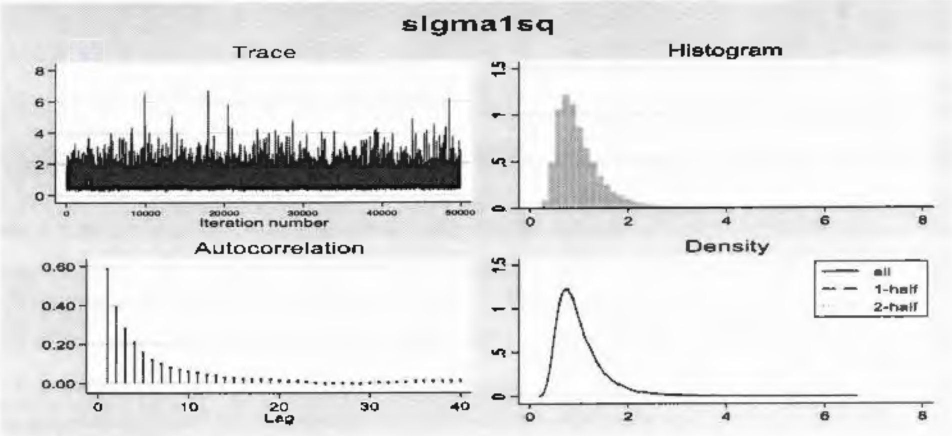
Appendix

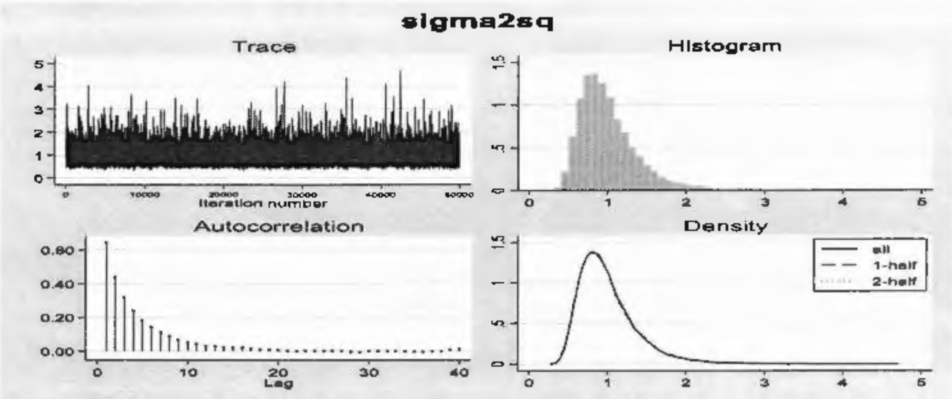
Table 4.8.1 for hyper prior parameters variances of normal distribution

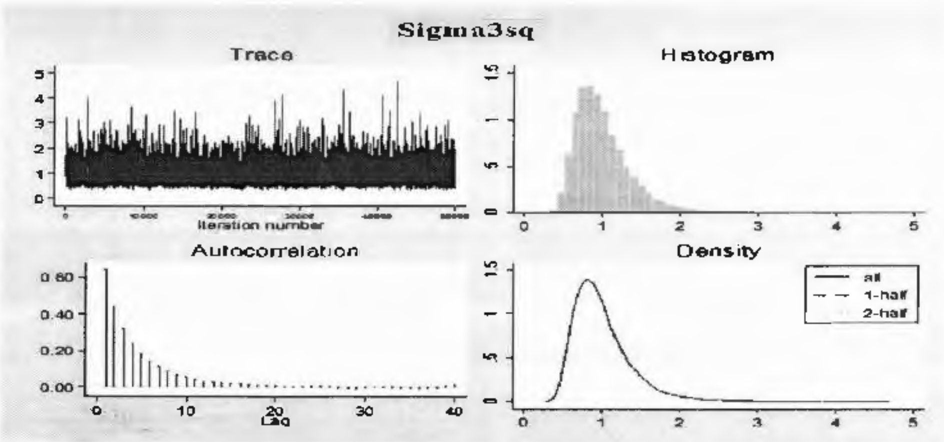
		Mean	*Std. Dev.*	*MCSE*	*Median*	[95% *Cred. Interval*	
	sigma1sq	.127	.0338	.0115	.1105	0.0594	0.1946
	Sigma2sq	.9002	0.313	.0126	.9001	.2750	1.0486
	Sigma3sq	.8015	.0098	.0207	.8008	.7856	.8227
	Sigma4sq	.7383	.0314	.0217	.7345	.6773	.8015
	Sigma5sq	.0126	.0003	.0115	.0115	.0119	.0115
	Sigma6sq	.0727	.0303	.0126	.0708	.0150	.1362
	Sigma7sq	.7272	.0012	.0207	.7008	.7248	.7270
	Sigma8sq	.1071	.0059	.0213	.0985	.0933	.1161
	Sigma9sq	.1173	.0114	.0119	.1101	.1075	.2500
	sigma10sq	.9002	.0424	.0225	.8967	.7350	1.0486
	sigma11sq	.8015	.0731	.0215	.8004	.6775	.9497
	sigma12sq	.7383	.0047	.0315	.7234	.5973	.8061
	Sigmad2sq	.1272	.0488	.0115	.1134	.1196	.5308
	Sigmad3sq	.9002	.0327	.0127	.9001	.7350	.9986
	Sigmad4sq	.8015	.0289	.0207	.8002	.6756	.8497
	Log marginal likelihood	-19232.8					

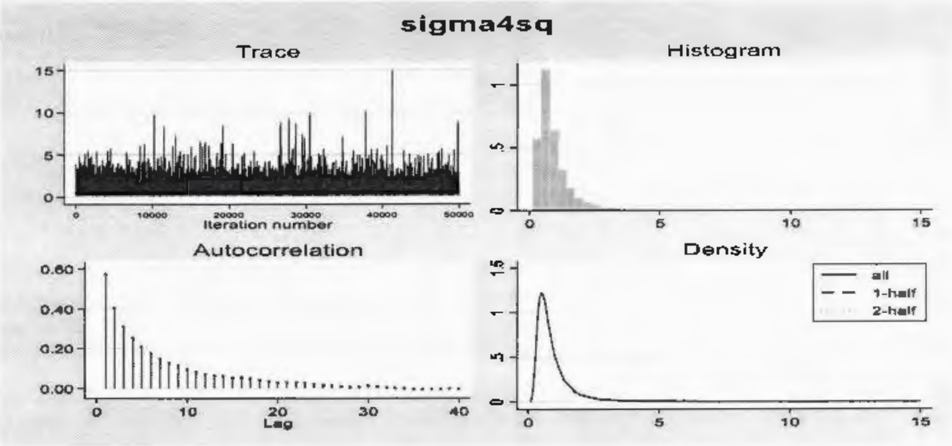
Appendix: A

In this appendix there are given trace plot, histogram, autocorrelation and density for hyperparameter.





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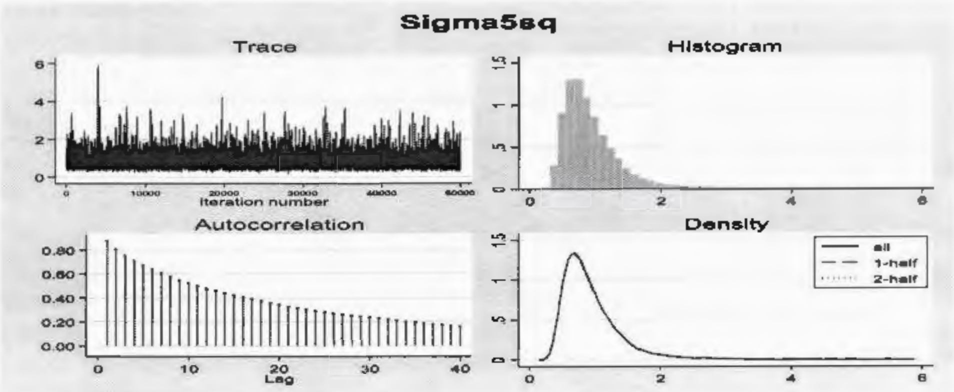
Histogram
Iteration number
Autocorrelation
Density
Lag
all
1-half
2-half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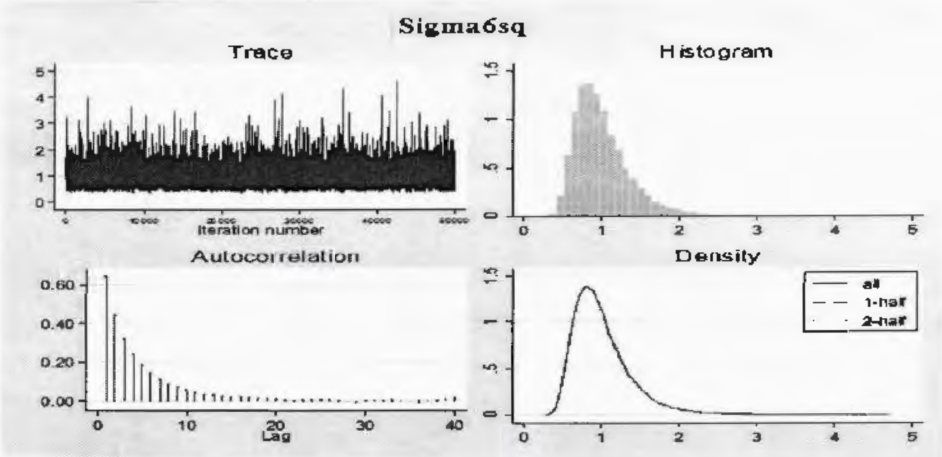
Histogram
Iteration number
Autocorrelation
Density
Lag
all
1-half
2-half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Histogram
Iteration number
Autocorrelation
Density
Lag
all
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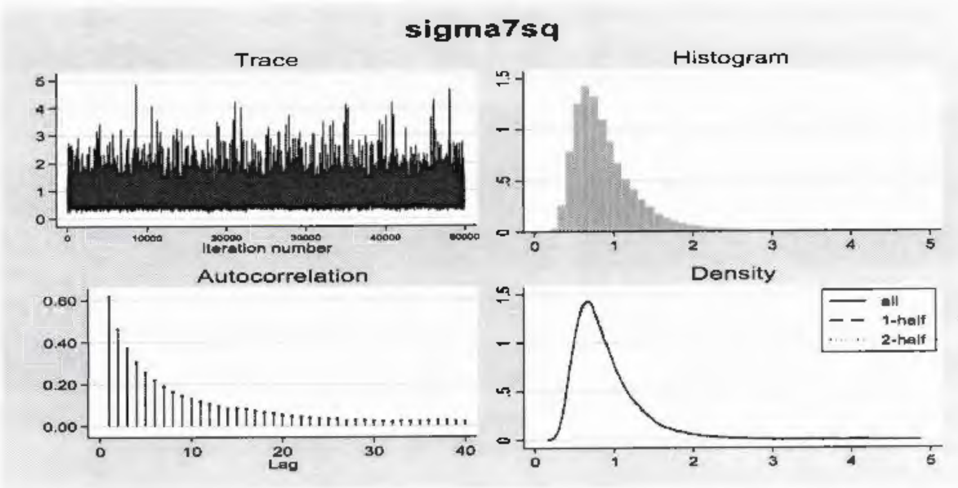
2-half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Histogram
Iteration number
Autocorrelation
Density
Lag
all
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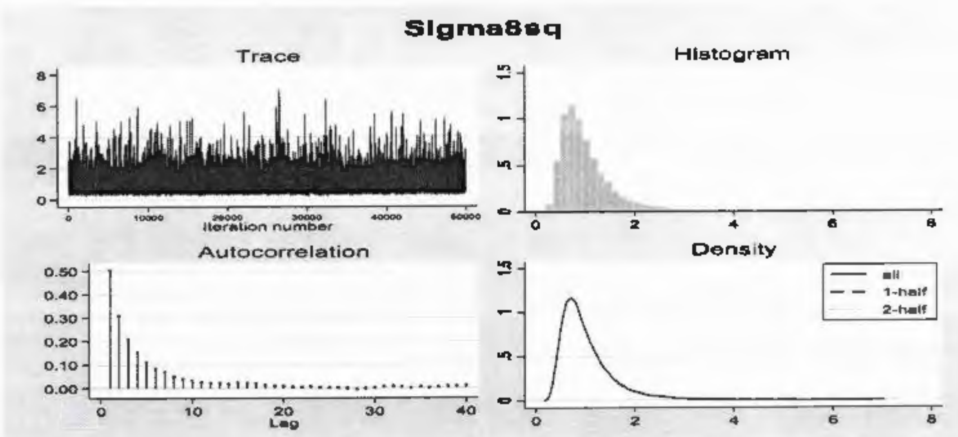
2-half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Trace
Histogram
Iteration number
Autocorrelation
Density
Lag
all
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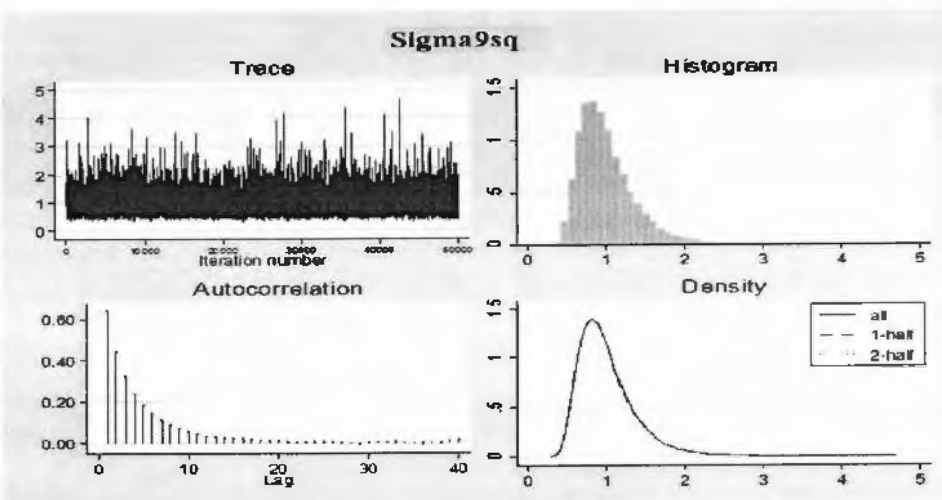
2-half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Histogram
Iteration number
Autocorrelation
Density
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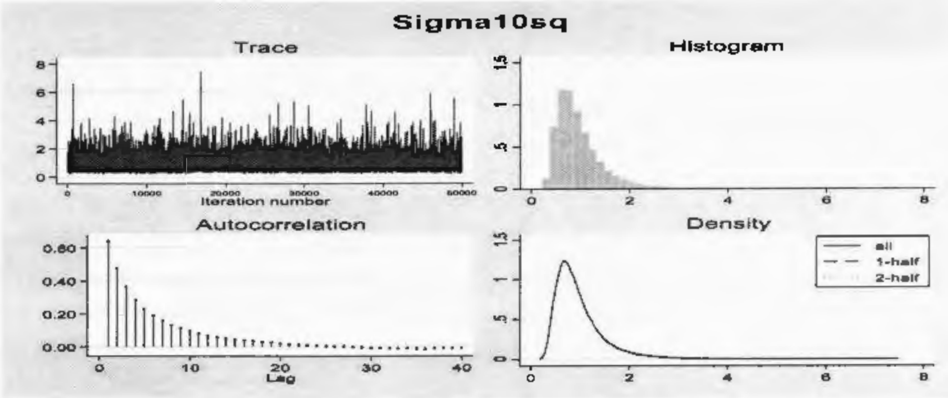
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Density
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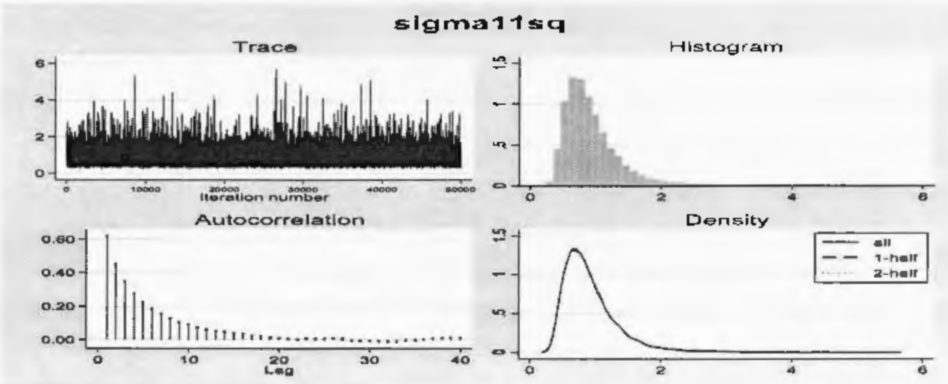
2-half
Lag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Autocorrelation
Density
all
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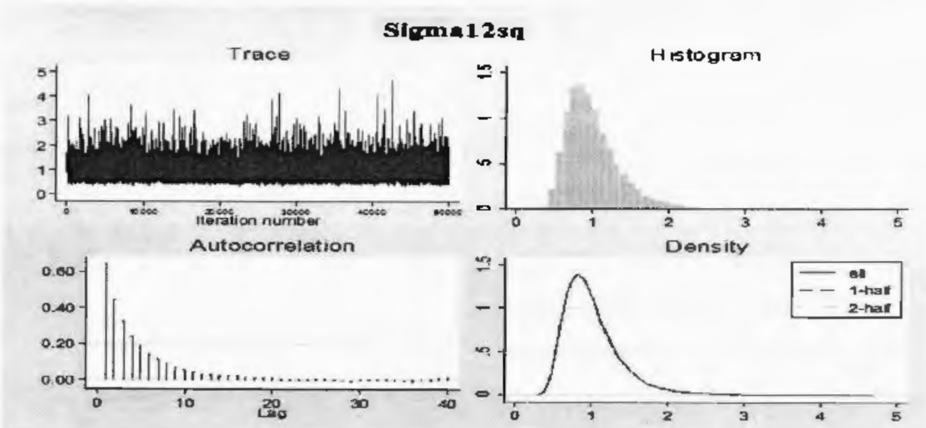
2-half
Lag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Autocorrelation
Density
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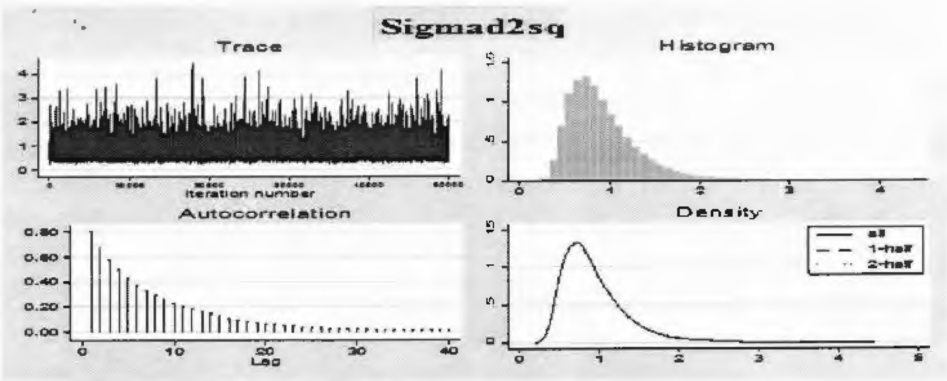
2-half
Lag


Sigmad2sq
Trace
Iteration number
Histogram
Autocorrelation
Lag
Density
all
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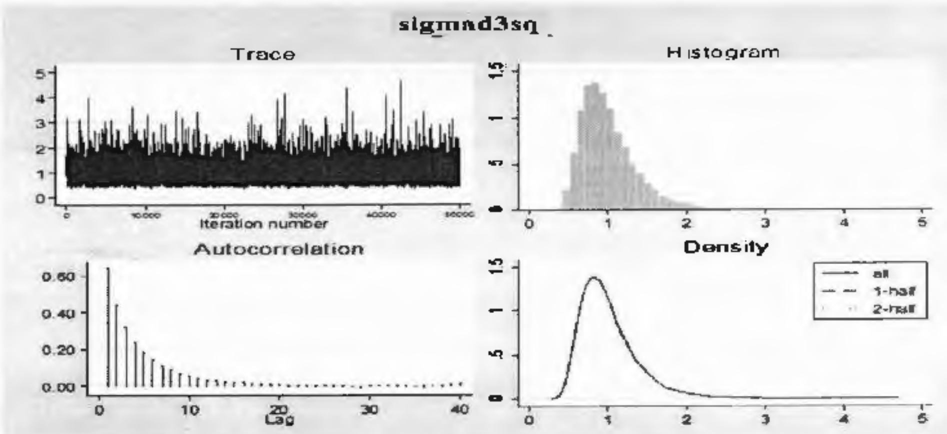
2-half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Iteration number
Histogram
Autocorrelation
Lag
Density
all
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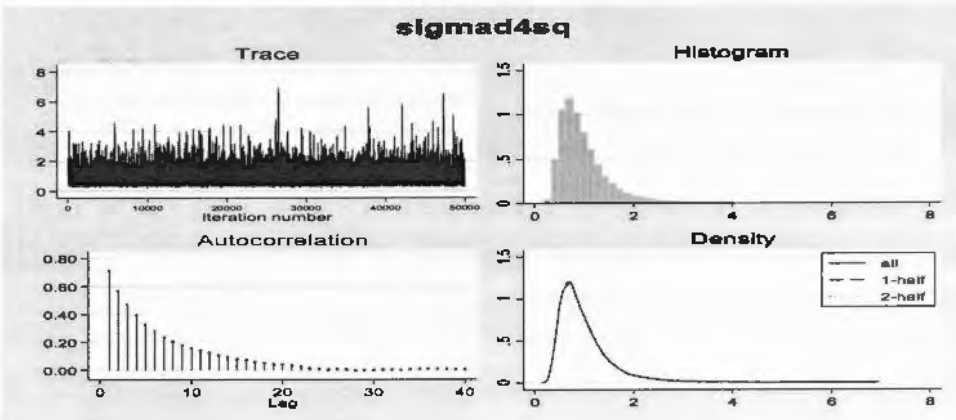
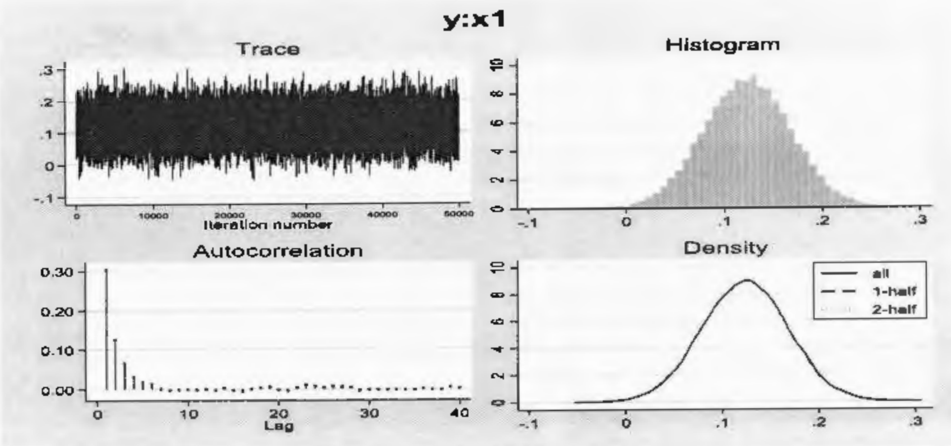
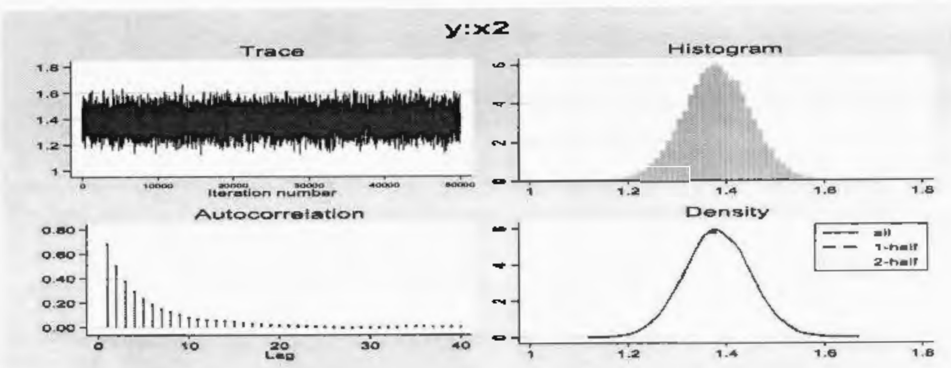
2-half

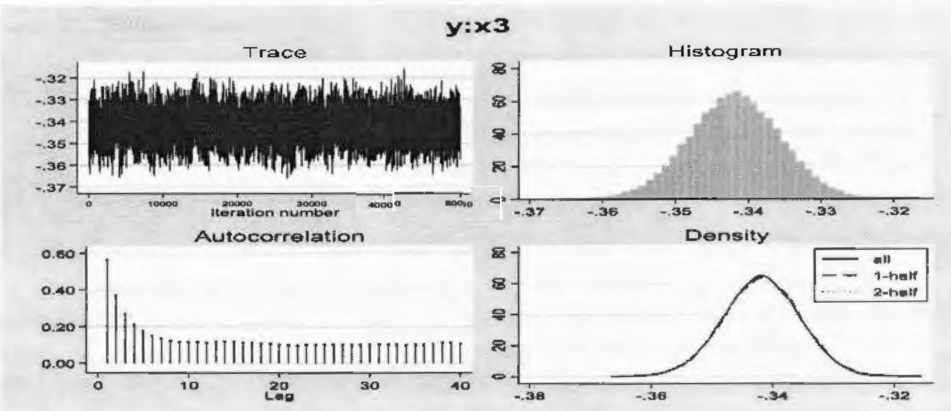

sigmad4sq
Trace
Iteration number
Histogram
Autocorrelation
Lag
Density
all
1-half
2-half

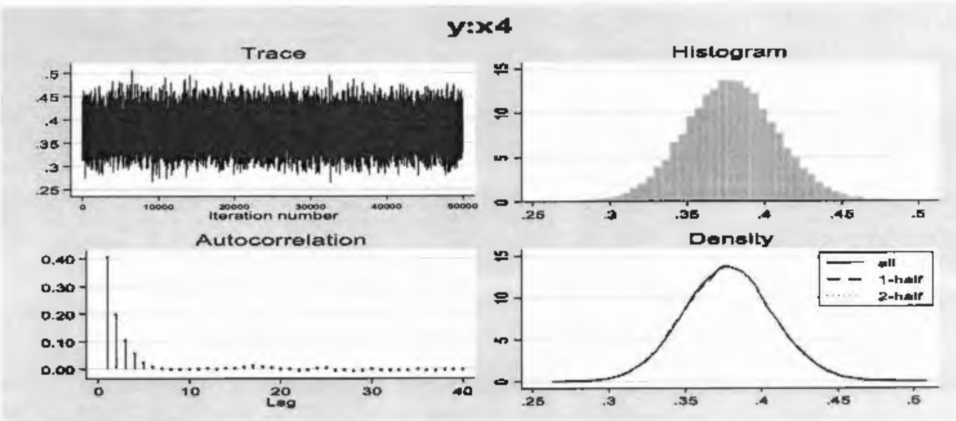
Appendix:B

In this appendix there are given trace plot, histogram, autocorrelation and density for parameters with non informative prior





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Iteration number
Histogram
Autocorrelation
Lag
Density
all
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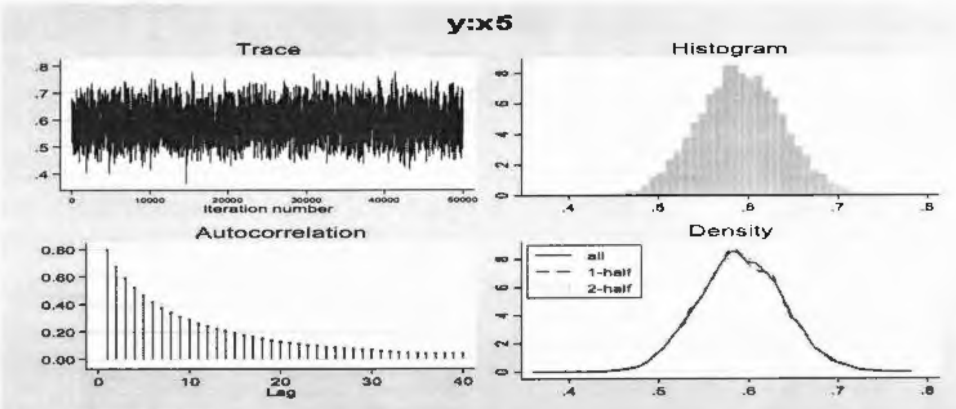
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Histogram
Autocorrelation
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Density
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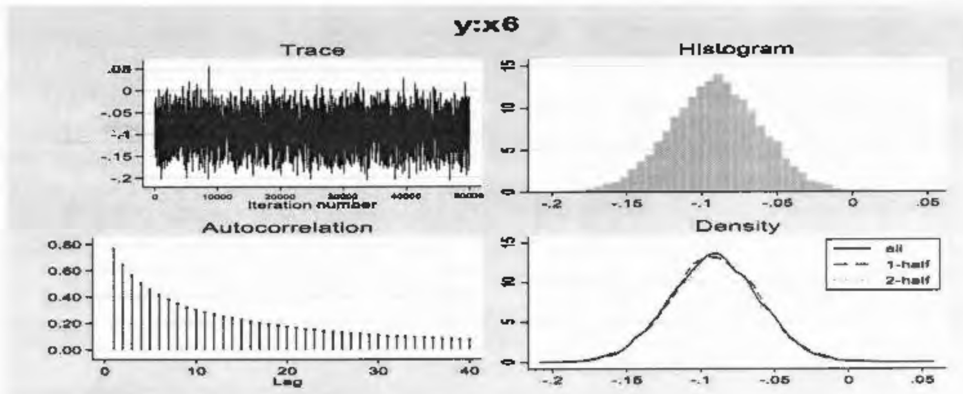
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Density
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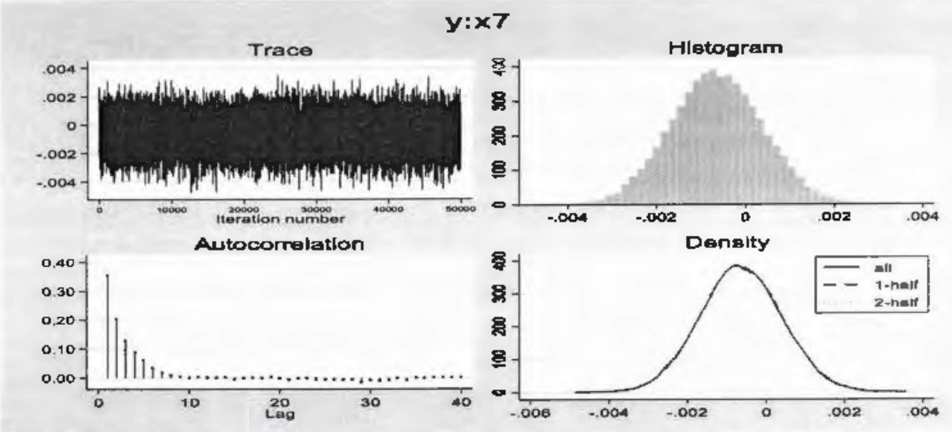
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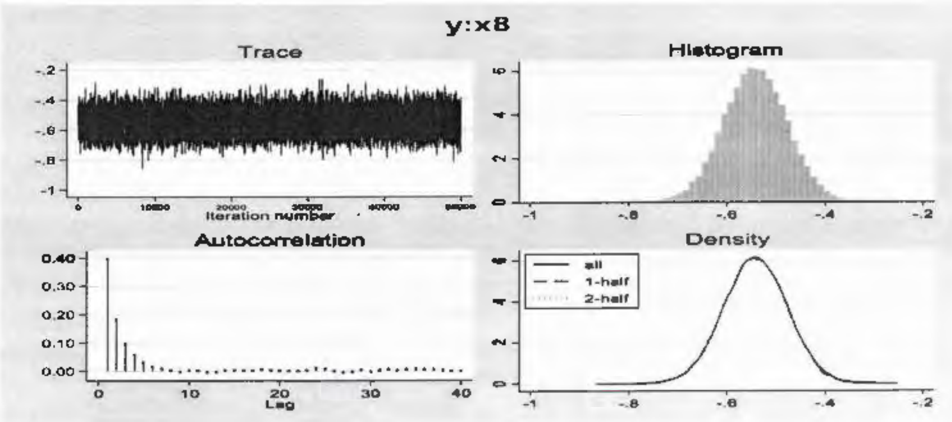
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Lag
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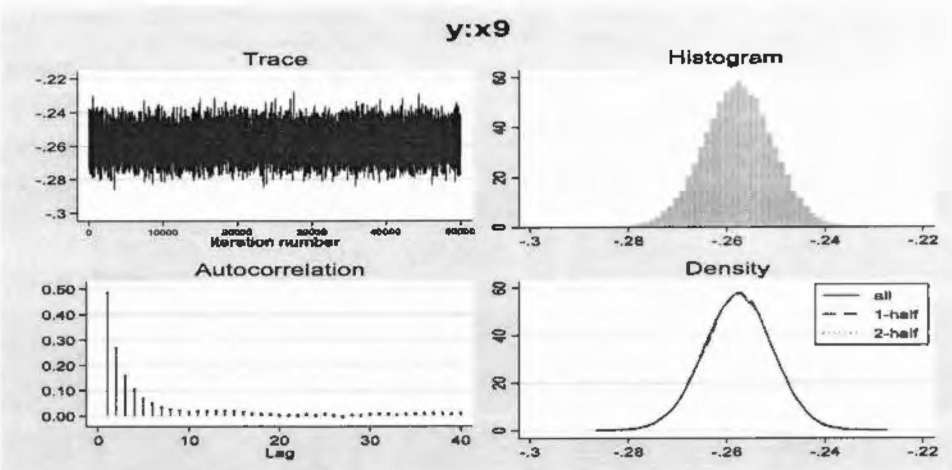
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Histogram
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Density
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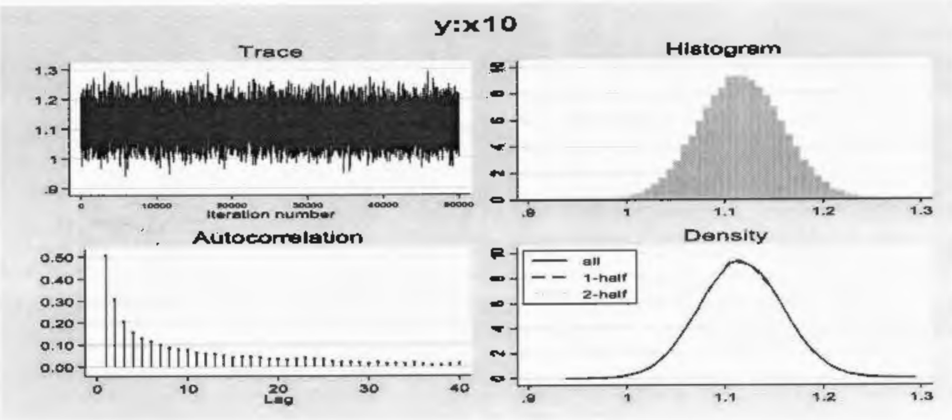
2-half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Autocorrelation
Density
all
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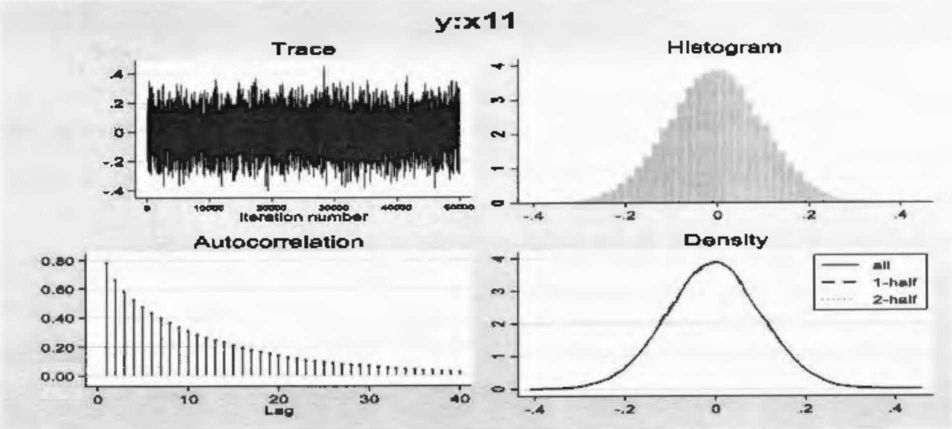
2-half
Lag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Density
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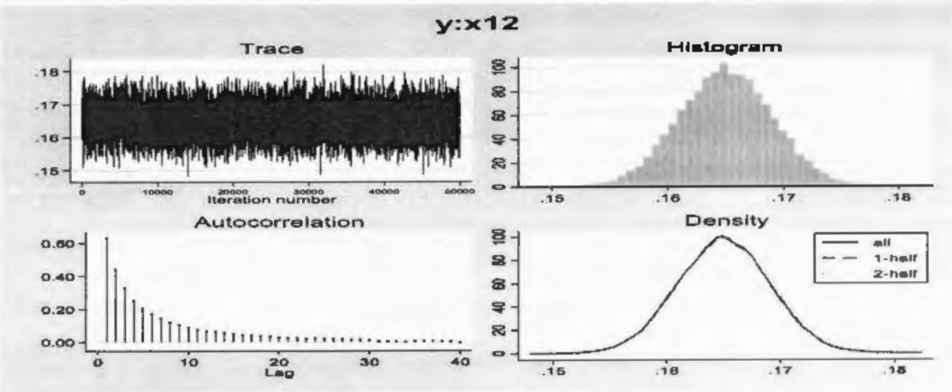
2-half
Lag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Density
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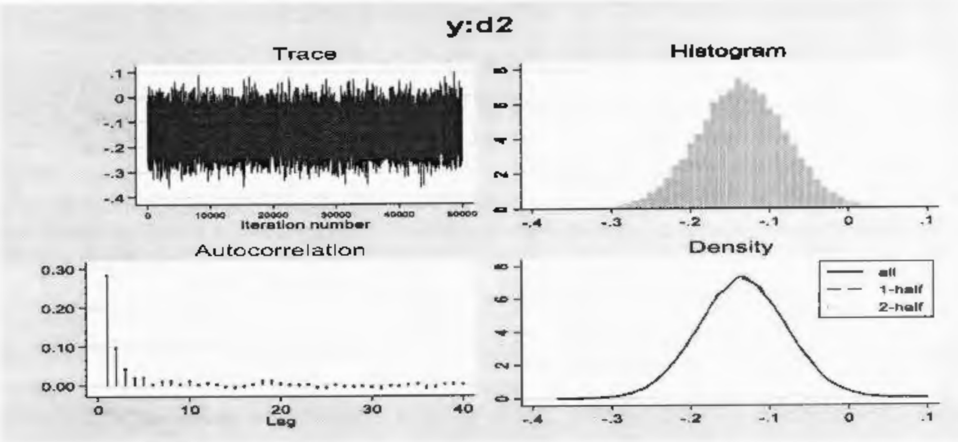
2-half
Lag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Iteration number
Histogram
Autocorrelation
Lag
Density
all
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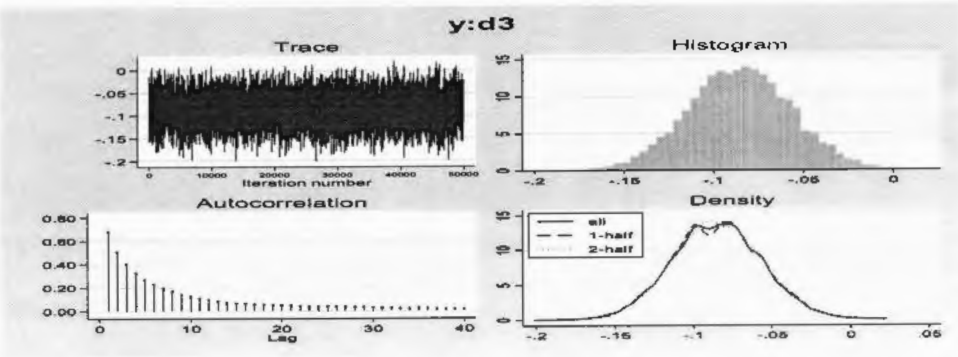
2-half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Histogram
Autocorrelation
Lag
Density
all
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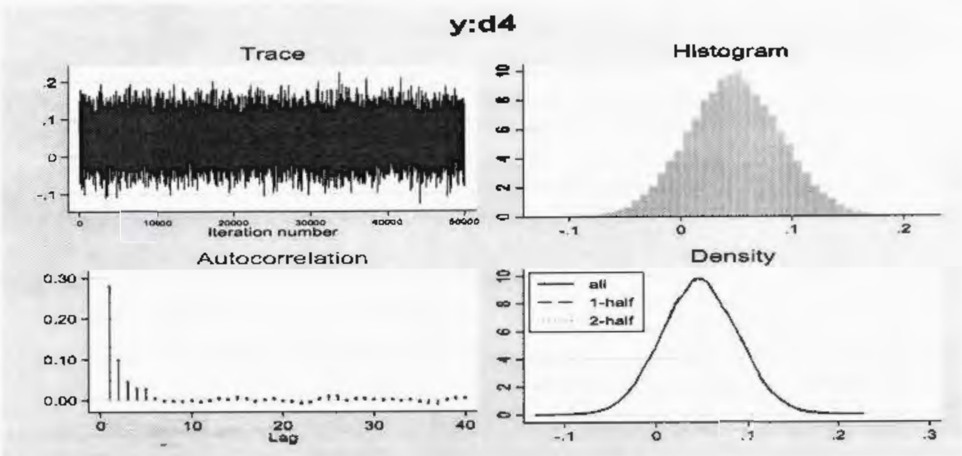
2-half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Trace
Iteration number
Histogram
Autocorrelation
Lag
Density
all
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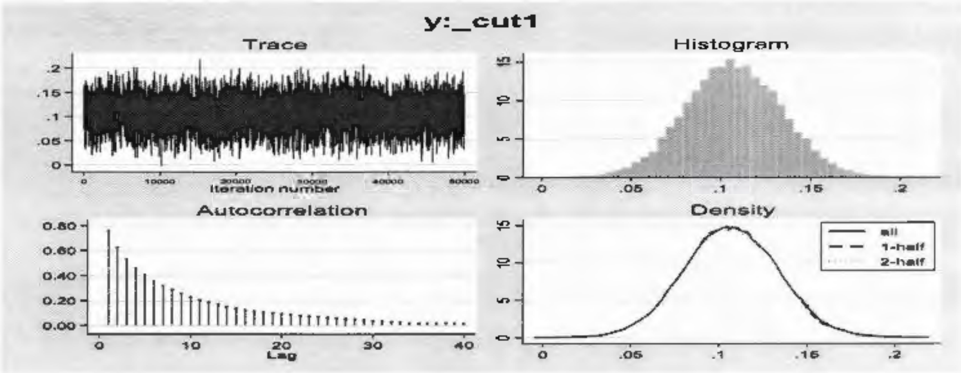
2-half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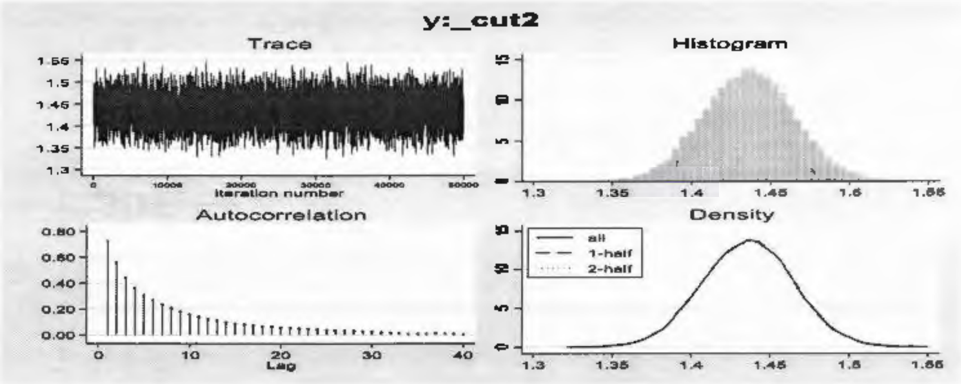
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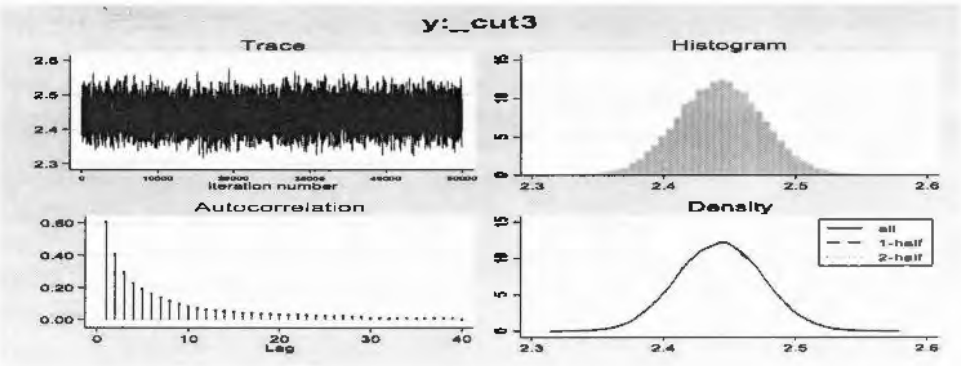
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Histogram
Autocorrelation
Lag
Density
all
1-half
2-half

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