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**PERFORMANCE ANALYSIS OF TURKISH
ELECTRIC DISTRIBUTION COMPANIES BY
DATA ENVELOPMENT ANALYSIS AND
UNIT REGRESSION ANALYSIS**

Ammar Mohammed Salih ALBASRI

DOKTORA TEZİ

İstatistik Anabilim Dalı

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Her Hakkı Saklıdır

TEZ BİLDİRİMİ

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İmza

Ammar Mohammed Salih ALBASRI

Tarih:

ÖZET

DOKTORA TEZİ

VERİ ZARFLAMA ANALİZİ VE (0,1) REGRESYON ANALİZİ İLE TÜRKİYE'DEKİ ELEKTRİK DAĞITIM ŞİRKETLERİNİN PERFORMANS ANALİZİ

Ammar Mohammed Salih ALBASRI

**Selçuk Üniversitesi Fen Bilimleri Enstitüsü
İstatistik Anabilim Dalı**

Danışman: Prof.Dr. Coşkun KUŞ

2021, 125 Sayfa

Jüri

Prof.Dr. Coşkun KUŞ

Prof.Dr. Buğra SARAÇOĞLU

Prof.Dr. Murat ERİŞOĞLU

Dr.Öğr.Üyesi Ahmet PEKGÖR

Dr.Öğr.Üyesi Kadir KARAKAYA

Elektrik enerjisi, bugün dünyamız için en iyi ve en önemli enerji türü olarak kabul edilmektedir. Ülkelerin kaydettikleri ilerlemenin tükettikleri elektrik enerjisi miktarıyla ölçüldüğü, yaşamın omurgası ve kalkınmanın kaynağıdır. Bu nedenle elektrik sektörü ülkelerin kalkınma politikalarında çok büyük önem taşımakta ve bir yatırım cazibe merkezidir. Elektrik dağıtım şirketleri, konut, sanayi, tarım, hizmet, araştırma, askeri ve diğer tüm sektörlerle elektrik sağlamaktan sorumlu oldukları için bu sektörün doğal yüzünü temsil etmektedir. Bu nedenle, bu çalışmanın ilk aşamasında, Türkiye'deki elektrik dağıtım şirketlerinin performansı, parametrik olmayan bir yöntem olan Veri Zarf Analizi (VZA) kullanılarak incelenmiştir. Elektrik dağıtım şirketleri, aynı girdi ve çıktılara sahip bu şirketlerin göreceli verimliliğini değerlendirmek için VZA modellerinde karar verme birimlerini (KVB'ler) temsil etti. VZA modellerinin oluşturulmasında Personel Sayısı, Yatırım Tutarı (TL), Trafo Kurulu Gücü (MVA), Kayıp-Kaçak (MWh) ve kablo uzunluğu (km) girdi olarak alınmıştır. Çıktılar Temin Edilen Enerji Miktarı (MWh), Dağıtım Şirketi Bölge Yüz ölçümü (km²), net tüketim (MWh) ve Abone Sayısıdır. Bu değişkenler, Türkiye'deki elektrik dağıtım şirketlerinin hizmet verimliliğini değerlendirmek için kullanılmıştır.

İkinci aşamada, birinci aşamadan elde ettiğimiz şirketler için etkinlik puanları bağımlı değişken olarak kabul edilmektedir. Ardından, performansı etkileyen dış değişkenlerin etkisi beta ve Kumaraswamy regresyon analizi ile incelenmiştir. Ayrıca beta ve Kumaraswamy regresyon analizinin yanı sıra yeni bir kantil tip regresyon analizi de önerilmiş ve verilerimize uygulanmıştır. Bu aşamada Köy ve Belde Sayısı, direk sayısı, dağıtım şirketi bölge nüfusu, yıllık arıza ve kesinti, trafo sayısı, armatür ve lamba sayısı değişkenlerinin verimlilik puanı üzerindeki etkileri incelenmiştir. Her şirket için yılda 15 spesifikasyon (değişken) ile 2007'den 2019'a kadar elektrik dağıtım şirketlerine ilişkin verileri kullandık. Sonuçlar, 21 şirketin 11'inin 13 yıl boyunca verimli olduğunu ve ayrıca dış değişkenlerin çoğunun puanlar üzerindeki etkisinin istatistiksel olarak anlamlı olduğunu gösteriyor.

Anahtar Kelimeler: Beta regresyon, Elektrik dağıtım şirketleri, Kumaraswamy regresyon, Veri zarflama analizi.

ABSTRACT

Ph.D. THESIS

PERFORMANCE ANALYSIS OF TURKISH ELECTRIC DISTRIBUTION COMPANIES BY DATA ENVELOPMENT ANALYSIS AND UNIT REGRESSION ANALYSIS

Ammar Mohammed Salih ALBASRI

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Jury

Prof.Dr. Coşkun KUŞ

Prof.Dr. Buğra SARAÇOĞLU

Prof.Dr. Murat ERİŞOĞLU

Asst.Prof.Dr. Ahmet PEKGÖR

Asst.Prof.Dr. Kadir KARAKAYA

Electric energy is considered the best and most important type of energy for our world today. It is the backbone of life and the source of development, where countries' progress is measured by the amount of electrical energy they consume. Therefore, the electricity industry occupies very great importance in the development policy of countries and is an investment attraction. Electricity distribution companies represent the actual front of this sector, as they are responsible for delivering electricity to all sectors, whether residential, industrial, agricultural, service, research, military, and others. Therefore, in the first stage of this study, the performance of electricity distribution companies in Turkey was examined using a non-parametric method, the Data Envelope Analysis (DEA). Electricity distribution companies represented decision-making units (DMUs) in DEA models to assess the relative efficiency of these companies, which have the same inputs and outputs. In building the DEA models, the number of employees, amount of investment (TL), installed power (MVA), power losses (MWh), and cable length (km) were taken as inputs. The outputs were total electricity generation (MWh), urban serviced area (km²), net consumption (MWh), and the number of customers. These variables were used to assess the service efficiency of the electricity distribution companies in Turkey.

In the second stage, the efficiency scores for companies, which we obtained from the first stage, are accepted as a dependent variable. Then, the effect of external variables affecting performance is examined by beta and Kumaraswamy regression analysis. In addition, a new quantile type regression analysis is also proposed, and it is applied to our data besides beta and Kumaraswamy regression analysis. At this stage, the effects of the variables of the number of villages and towns, number of poles, distribution company region population, annual breakdown and interruption, number of transformers, and the number of fixtures and lamps on the efficiency score were examined. We used data on electricity distribution companies from 2007 to 2019, with 15 specifications (variable) for each company per year. The results show that 11 of the 21 companies are still efficient, along 13 years, and also, the effect of most of the external variables on the scores is statistically significant.

Keywords: Beta regression, Data envelopment analysis, Electricity distribution companies, Quantile regression.

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CONTENTS

ÖZET	iv
ABSTRACT.....	v
ÖNSÖZ	vi
CONTENTS	vii
LIST OF TABLES	ix
LIST OF FIGURES	xiii
LIST OF CHARTS	xv
LIST OF ABBREVIATIONS	xvi
1. INTRODUCTION	1
2. LITERATURE REVIEW	7
3. DATA ENVELOPMENT ANALYSIS AND REGRESSION MODELS	22
3.1. The First Stage: Data Envelopment Analysis	22
3.1.1. Efficient frontier	22
3.1.2. Data envelopment analysis models	24
3.1.2.1. Charnes-Cooper-Rhodes model or constant returns to scale	24
3.1.2.2. Banker-Charnes-Cooper model or variable returns to scale	25
3.2. The Second Stage: Regression Models	26
3.2.1. An alternative quantile regression model	26
3.2.2. Maximum likelihood estimation method for the model parameters	29
3.3. Data Description	30
4. THE FIRST STAGE: DATA ENVELOPMENT ANALYSIS APPLICATION	33
4.1. Variables of Data Envelopment Analysis	33
4.2. Data Envelopment Analysis Models	35
4.3. Results of Data Envelopment Analysis	36
4.4. Conclusions of The First Stage: Applying Some Models	43
5. THE SECOND STAGE: APPLICATION OF QUANTILE REGRESSION ANALYSIS	47

5.1. Operations To Be Performed In A Regression Analysis	47
5.1.1. Regression analysis.....	47
5.1.2 Maximum likelihood estimation.....	47
5.1.3 Model validity.....	48
5.1.4. R program	48
5.2. Results Of Regression Analysis.....	48
5.3. Conclusions Of The Second Stage Applying Regression Analysis.....	127
5.3.1. The first angle: analyzes the ML values of the three regression equations for some models	128
5.3.2. The second angle: is by analyzing the results of tests for goodness of fit..	131
5.3.3. Concluding remarks on UGHN regression.....	134
REFERENCES.....	135
CV.....	139

LIST OF TABLES

Table	Page
Table 3.1. Electricity distribution companies and their regions.....	31
Table 3.2. The variables that were collected about electricity distribution companies..	32
Table 4.1. Showing how often the variables are used as input and output in the literature review.....	34
Table 4.2. Input and output variables for DEA and regression variables.....	35
Table 4.3. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2007.....	36
Table 4.4. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2008.....	37
Table 4.5. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2009.....	37
Table 4.6. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2010.....	38
Table 4.7. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2011.....	38
Table 4.8. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2012.....	39
Table 4.9. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2013.....	39
Table 4.10. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2014.....	40
Table 4.11. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2015.....	40
Table 4.12. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2016.....	41
Table 4.13. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2017.....	41
Table 4.14. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2018.....	42

Table 4.15. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2019.....	42
Table 4.16. Shows the number of times that each company achieved complete relative efficiency by applying the models (CCR-I, CCR-O, BCC-I, BCC-O) for 13 years.....	45
Table 4.17. Shows the number of companies that achieved the complete relative efficiency every year by applying the models (CCR-I, CCR-O, BCC-I, BCC-O) for 13 years.....	46
Table 5.1. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2007.....	50
Table 5.2. The results of testing the goodness of fit for the residual of the regression models for BCCI 2007.....	52
Table 5.3. The results of testing the goodness of fit for the residual of the regression models for BCCO 2007.....	54
Table 5.4. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2008.....	56
Table 5.5. The results of testing the goodness of fit for the residual of the regression models for BCCI 2008.....	58
Table 5.6. The results of testing the goodness of fit for the residual of the regression models for BCCO 2008.....	60
Table 5.7. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2009.....	62
Table 5.8. The results of testing the goodness of fit for the residual of the regression models for BCCI 2009.....	64
Table 5.9. The results of testing the goodness of fit for the residual of the regression models for BCCO 2009.....	66
Table 5.10. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2010	68
Table 5.11. The results of testing the goodness of fit for the residual of the regression models for BCCI 2010.....	70
Table 5.12. The results of testing the goodness of fit for the residual of the regression models for BCCO 2010.....	72
Table 5.13. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2011.....	74
Table 5.14. The results of testing the goodness of fit for the residual of the regression models for BCCI 2011.....	76

Table 5.15. The results of testing the goodness of fit for the residual of the regression models for BCCO 2011.....	78
Table 5.16. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2012.....	80
Table 5.17. The results of testing the goodness of fit for the residual of the regression models for BCCI 2012.....	82
Table 5.18. The results of testing the goodness of fit for the residual of the regression models for BCCO 2012.....	84
Table 5.19. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2013.....	86
Table 5.20. The results of testing the goodness of fit for the residual of the regression models for BCCI 2013.....	88
Table 5.21. The results of testing the goodness of fit for the residual of the regression models for BCCO 2013.....	90
Table 5.22. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2014.....	92
Table 5.23. The results of testing the goodness of fit for the residual of the regression models for BCCI 2014.....	94
Table 5.24. The results of testing the goodness of fit for the residual of the regression models for BCCO 2014.....	96
Table 5.25. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2015.....	98
Table 5.26. The results of testing the goodness of fit for the residual of the regression models for BCCI 2015.....	100
Table 5.27. The results of testing the goodness of fit for the residual of the regression models for BCCO 2015.....	102
Table 5.28. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2016.....	104
Table 5.29. The results of testing the goodness of fit for the residual of the regression models For BCCI 2016.....	106
Table 5.30. The results of testing the goodness of fit for the residual of the regression models for BCCO 2016.....	108
Table 5.31. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2017.....	110

Table 5.32. The results of testing the goodness of fit for the residual of the regression models for BCCI 2017.....	112
Table 5.33. The results of testing the goodness of fit for the residual of the regression models for BCCO 2017.....	114
Table 5.34. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2018.....	116
Table 5.35. The results of testing the goodness of fit for the residual of the regression models for BCCI 2018.....	114
Table 5.36. The results of testing the goodness of fit for the residual of the regression models for BCCO 2018.....	120
Table 5.37. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2019.....	122
Table 5.38. The results of testing the goodness of fit for the residual of the regression models for BCCI 2019.....	124
Table 5.39. The results of testing the goodness of fit for the residual of the regression models for BCCO 2019.....	126
Table 5.40. ML values of the regression models (Beta, Kumaraswamy, UGHN) constructed for the DEA equations (CCR-I/O, BCC-I, BCC-O), 2007-2019.....	129
Table 5.41. The number and the percentage of successes that each regression model achieved as the best among the other regressions.....	132
Table 5.42. The number of successes that each regression model achieved as the best among the other regressions.....	132
Table 5.43. Shows the Percentages of successes that each regression model achieved as the best among the other regressions.....	133

LIST OF FIGURES

Figure	Page
Figure 3.1. Input-Oriented performance measurement with DEA.....	23
Figure 3.2. A map of Turkey on which the electricity distribution companies and their regions are distributed.....	32
Figure 5.1. The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2007.....	50
Figure 5.2. The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2007.....	52
Figure 5.3. The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2007.....	54
Figure 5.4. The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2008.....	56
Figure 5.5. The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2008.....	58
Figure 5.6. The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2008.....	60
Figure 5.7. The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2009.....	62
Figure 5.8. The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2009.....	64
Figure 5.9. The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2009.....	66
Figure 5.10. The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2010.....	68
Figure 5.11. The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2010.....	70
Figure 5.12. The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2010.....	72
Figure 5.13. The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2011.....	74
Figure 5.14. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2011.....	76
Figure 5.15. The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2011.....	78
Figure 5.16. The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2012.....	80
Figure 5.17. The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2012.....	82
Figure 5.18. The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2012.....	84
Figure 5.19. The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2013.....	86
Figure 5.20. The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2013.....	88
Figure 5.21. The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2013.....	90

Figure 5.22.	The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2014.....	92
Figure 5.23.	The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2014.....	94
Figure 5.24.	The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2014.....	96
Figure 5.25.	The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2015.....	98
Figure 5.26.	The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2015.....	100
Figure 5.27.	The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2015.....	102
Figure 5.28.	The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 201.....	104
Figure 5.29.	The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2016.....	106
Figure 5.30.	The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2016.....	108
Figure 5.31.	The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2017...	110
Figure 5.32.	The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2017.....	112
Figure 5.33.	The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2017.....	114
Figure 5.34.	The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2018...	116
Figure 5.35.	The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2018.....	118
Figure 5.36.	The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2018.....	120
Figure 5.37.	The regression of (Beta, Kumaraswamy, UGHN) for CCRI/O 2019...	122
Figure 5.38.	The regression of (Beta, Kumaraswamy, UGHN) for BCCI 2019.....	124
Figure 5.39.	The regression of (Beta, Kumaraswamy, UGHN) for BCCO 2019.....	126

LIST OF CHARTS

Chart	Page
Chart 4.1. Input and output variables.....	34
Chart 4.2. The frequency of the efficiency of companies over 13 years.....	45
Chart 4.3. The percentage of overall relative efficiency achieved by the distribution companies annually over 13 years.....	47
Chart 5.1. ML values of the regression models (Beta, Kumaraswamy, UGHN) constructed for the CCR-I/O model, 2007-2019.....	129
Chart 5.2. ML values of the regression models (Beta, Kumaraswamy, UGHN) constructed for the BCC-I model, 2007-2019.....	130
Chart 5.3. ML values of the regression models (Beta, Kumaraswamy, UGHN) constructed for the BCC- O model, 2007-2019.....	130
Chart 5.4. The frequency of successes achieved by each regression of (Beta, Kumaraswamy, UGHN) in the three tests.....	132
Chart 5.5. The percentage of successes achieved by each regression of (Beta, Kumaraswamy, UGHN) in the three tests.....	133

LIST OF ABBREVIATIONS

AHP	: Analytic Hierarchy Process
BCC	: Banker, Charnes & Cooper OR Variable Returns to Scale VRS .
BCC-I	: Input-Oriented BCC.
BCC-O	: Output-Oriented BCC.
CCR	: Charnes, Cooper & Rhodes OR Constant Returns to Scale CRS .
CCR-I	: Input-Oriented CCR.
CCR-O	: Output-Oriented CCR.
CRS	: Constant Returns to Scale.
DEA	: Data Envelopment Analysis.
DMUs	: Decision-Making Units.
EDAŞ	: (Elektrik Dağıtım Anonim Şirketi) Electricity Distribution Company.
EDDs	: Electricity Distribution Divisions.
EPDK	: (Enerji Piyasası Düzenleme Kurumu) Energy Market Regulation Authority (EMRA).
EPK	: (Enerji Piyasası Kanunu) Law of Electricity Market.
EÜAŞ	: (Elektrik Üretim Anonim Şirketi) Electricity Generation Company.
FAHP	: Fuzzy Analytic Hierarchy Process.
GHN	: Generalized Half Normal Distribution.
GW	: Gigawatt.
GWh	: Gigawatt-Hour.
Km	: Kilometer.
km²	: Square Kilometer.
kVA	: Kilovolt-Ampere.
kW	: Kilowatts.
kWh	: Kilowatts-hour.
maxLik	: A Function In The R Program
MENR	: Ministry of Energy and Natural Resources.
ML	: Maximum Likelihood.
MLE	: Maximum Likelihood Estimation.
MVA	: Megavolt-Ampere.
MW	: Megawatt.

MWh	: Megawatt-hour.
OECD	: Organization for Economic Co-operation and Development.
OPEX	: Operational Expenses OR Operating Expenditure.
RTS	: Returns to Scale.
SFA	: Stochastic Frontier Analysis.
SOM	: Self-Organizing Maps.
TEAŞ	: (Türkiye Elektrik Üretim İletim Anonim Şirketi) Turkish Electricity Generation and Transmission Company.
TEDAŞ	: (Türkiye Elektrik Dağıtım Anonim Şirketi) Turkish Electricity Distribution Company.
TEİAŞ	: (Türkiye Elektrik İletim Anonim Şirketi) Turkish Electricity Transmission Company.
TEK	: (Türkiye Elektrik Kurumu) Turkish Electricity Authority.
TETAŞ	: (Türkiye Elektrik Ticaret ve Taahhüt Anonim Şirketi) Turkish Electricity Trading and Contracting Company.
TL	: Turkish lira.
TOM	: Total Operating Expenses.
TOPSIS	: Technique for Order Preference by Similarity to Ideal Solution.
TPC	: Taiwan Power Company.
UGHN	: Unit Generalized Half Normal Distribution.
UPCL	: Uttarakhand Power Corporation Limited.
USDEA	: Unified Super Data Envelopment Analysis.
VRS	: Variable Return to Scale.

1. INTRODUCTION

Electricity has great and unlimited importance in life. It is one of humanity's most significant technological innovations throughout the ages, and today one cannot think of a world without electricity; it has become an integral part of our daily life. Today, electricity is an essential part and pillar of homes, universities, institutions, factories, and even streets. For example, almost all homes, companies, institutions, and factories are powered by electricity.

On the other hand, globally, many factories and companies manufacturing machinery and cars today seek to rely on electric energy in production, as well as to make their products run on electrical power to reduce the harmful waste to the environment resulting from the combustion of gas, gasoline and gas oil used as fuel for these mechanisms. Because of the importance of electricity in daily life, the global demand for it is constantly increasing. It is essential for our everyday life, and it has become equally important in agriculture, industry, scientific research, medicine, and many others. Statistics show the increasing amount of electric energy consumed by countries annually and the relative consumption of these countries based on their population. So every country aspires to provide a regular, sustainable and affordable supply of electricity to its citizens. However, over the past 30 years, some countries have made giant leaps, while others have seen little progress in generating electricity.

Every day that passes us, our need for electric energy increases. Today, and in light of the significant development the world is witnessing, it is one of the essential energy sources in human life and even more critical than ever. Therefore, many countries of the world have sought to adopt unique plans and procedures, in The way to develop energy sources and establish additional stations and projects to provide electricity, and adopt various renewable and non-traditional sources to produce cheap electric energy with little harm to the environment.

The global investment in clean energy in recent years, according to some reports, has reached very high and record levels. We also see the world's tendency to rely heavily on clean energy (solar, wind, sea waves, waterfalls, etc.) and use it as an alternative to fossil energy sources such as coal and oil. For example, the value of Turkish

investments in renewable energy used in electricity generation in 2020 amounted to \$7 billion, which is equivalent to 99.6 percent of new investments in the electric power generation sector for that year in Turkey, where the increase in production capacity amounted to about 4800 MW. The increase in the production capacity of electric energy through renewable energy sources in 2020 is the largest of its kind in one year, in the history of Turkey, as the total increase recorded in electricity generation for that year was by renewable energy only. The percentage of the most significant investment was in hydroelectric power plants, then wind plants, then solar energy, then bioenergy plants, waste heat, and geothermal power plants, respectively.

The increase in the production capacity of electric energy during 2021, according to the strategic plan of the Turkish Ministry of Energy and Natural Resources, is expected to reach about two thousand and 100 megawatts, with an investment value of \$2.5 billion. It is worth noting that Turkey has made great strides in recent years in relying on renewable energy to generate electricity, thanks to investments in this field. Turkey is seventh in Europe in the production of wind and solar power, and globally it occupies 12th place in wind energy production with 9660 megawatts, and ranked The 13th in the field of solar energy, with 7,145 megawatts.

The Turkish electricity sector has witnessed significant growth and development since the beginning of the 1970s. The electricity generation capacity increased from 2,235 MW in 1970 to 91,267 MW in 2019, with an annual average increase rate of 7.86%. As a result, the amount of electricity produced was increased from 8,623 GWh to 288.558.6 GWh through the identical period, showing an average yearly growth of 7.43%. Thanks to these exponential increase rates, in 2019, the Turkish per capita consumption of electricity increased to 3,403 kWh. But, it is yet below the OECD average per capita expenditure of 8,756 kWh.

To advance the electricity sector, many countries, since 1990, started to reform the electricity sector with a focus on the market; These reforms ranged from creating independent regulators to privatizing parts of the electricity industry, restructuring utilities, and allowing competition.

Privatization is a method of thinking and a practical device based on conceiving a unique system for dividing the work and tasks of the national economy among the

government and the private division. It is a one-way kind of work, which is the possibility of the government and the public division giving up some tasks and activities to the private sector, and not in the opposite direction. Within this framework, the purposes of privatization are defined to perform the following:

- Increasing economic performance in the country for the management of funds.
- Reduces stress on the general state budget regarding state aid and compensation for public companies' losses.
- possessing a more significant percentage of ownership for individual stakeholders, which provides an increase in production and export and a rise in overall quality.
- State cash obtained from the sale of state-owned property, which is now available to cover the state's budget deficit.
- Realizing that internal control and accounting systems in public agencies are inefficient. (Foster & Rana, 2019)

In all world countries, including Turkey, electric energy passes through three essential stages until it reaches the consumer. These stages are generation, transmission, and distribution. The electricity sector in Turkey was under the control of a huge state-owned company called the Turkish Electricity Authority (TEK), which was an integrated and vertically dominant institution in the fields of generation, transmission, and distribution of electricity to all parts of Turkey, similar to what is found in most countries around the world. In 1994 TEK was separated into two companies, the Turkish Electricity Generation and Transmission Company TEAŞ and the Turkish Electricity Distribution Company TEDAŞ. After that, the Turkish government launched its comprehensive reform program for electricity to free it from the hands of the state and put it in the investment and competition market, and make it run by private companies that undertake the task of generating, transmitting, and distributing electricity, and that was within the enactment of the Law of Electricity Market (EPK) No. 4628 in 2001.

With the entry into force of the Electricity Market Law in 2001, the process of opening the generation activity that the state had previously carried out began, as the private sector participated in the implementation through some investment models. The Energy Market Regulatory Authority (EMRA) was tasked with regulating the transmission and distribution sectors. In addition to this, it was also charged with carrying out other duties, including licensing, monitoring, and auditing, so EMRA's responsibilities were

not restricted to regulating only natural monopolies. The Electricity Market Law Reform Program, supported by several organizations, including environmental groups, predicts that electricity generation, transmission, and distribution activities will be divided. The generation and distribution assets will be privatized once the asset transfer has been completed.

Based on what was stated in the reform program and the Electricity Market Law, in 2002, TEAŞ was divided into three companies, Electricity Generating Company (EÜAŞ), Turkish Electricity Trading and Contracting Company (TETAŞ), Turkish Electricity Transmission Company (TEİAŞ), and these companies are responsible for electricity generation, wholesale trade, and transportation activities, respectively.

The government approved the Electricity Sector Strategy Plan in 2004 and determined the necessary steps to liberalize the Turkish electricity market. On this basis, privatization will begin in the distribution sector (TEDAŞ) and will be continued in generation assets (EÜAŞ). The restructuring process continued in the following years as the Turkish electricity distribution network was divided into 21 regions after many mergers between TEDA's electricity distribution companies. In each of TEDA's 21 distribution areas, a separate distribution company was founded. Despite what was planned in the strategic working document, the privatization of electricity distribution companies would begin in 2005 and end in 2006, but this was not fulfilled. The privatization process did not end until 2013 when the privatization of electricity distribution was completed in all regions. Today it is the Implementation of electricity distribution activities by private electricity distribution companies (EDAŞ) in 21 areas. Then, as the privatization of distribution companies came to an end, the privatization of electricity generation assets began, as planned in the strategic plan. All private electricity distribution companies whose privatization was completed in 2013 are monitored and audited by EMRA. In addition, electricity distribution companies are periodically audited by the Ministry of Energy and Natural Resources (MENR) within the Electricity Distribution Companies Inspection Regulation scope. The expected benefits of electricity sector reform and privatization, including cost reduction through efficient and effective electricity generation and distribution assets, were formally included in the strategic document. The strategy document also stated that the primary goal of the electricity sector reform is to achieve lower tariffs by increasing the sector's efficiency. Hence the great importance of the activity of electricity distribution companies, as it is the outlet through which electricity is delivered to the final

consumer, and therefore it is the actual interface that reflects the extent of efficiency, quality, and consumer satisfaction with the electricity sector. It is the absolute criterion for the success of liberalizing electricity markets and opening them to a competitive environment through Providing high-quality, low-cost continuous electricity to consumers. Based on the foregoing, we find that the Turkish electricity distribution sector has been completely privatized.

When we want to arrange and organize electricity distribution utilities, past productivity improvement performance estimates are significant for determining future requirements. Therefore, it is also essential to recognize the many parametric and non-parametric approaches developed to analyze performance indicators and thus Evaluate the efficiency of its units and review the allocation of resources to ineffective units according to the results obtained. Among the best of these methods is the DEA method because of its good features and high flexibility, making it easy to use and giving excellent and accurate scientific and practical results. The data envelopment analysis method is a new quantitative tool from the operations research tools to measure the relative efficiency of administrative units with similar objectives and activities to determine the efficiency of each one of these units by determining the optimal mix of inputs and outputs. Furthermore, it is a nonparametric method that depends on the Linear Programming methodology, as it evaluates the relative efficiency for many similar organizations. DEA is a powerful optimization tool applied to evaluate the performance of any sectoral system in terms of both technical and allocative performance, and it is a multi-criterion decision-making tool. The Decision-Making Units DMUs are compared to Corresponding points on the frontier. The frontier is the best actual functional frontier based upon the current real set of data. (Kumar, Singh, Verma, Venkatesh, & Gupta, 2017).

In this thesis, in the first stage, we measure the efficiency of the work of 21 private electricity distribution companies for the period from 2007 to 2019 using the data envelope analysis method. In the second stage, the efficiency scores of firms obtained from the first stage are considered dependent variables, and the effect of external variables affecting performance is examined through beta and Kumarswamy regression analysis. In addition, a new quantitative-type regression analysis was also proposed, and the three regressions were applied to our data. As a result, most external variables on the degree of efficiency of companies were statistically significant.

The nest of the thesis is given as follows:

Chapter 1 introduces the necessity of electricity in our world and the importance of relying on renewable energy to generate electricity. It also mentions the importance and benefits of privatizing this sector and relying on private companies in generation and distribution. The stages of development of the electricity sector in Turkey and its transformations up to the present time were also mentioned. Finally, the DEA and its importance in measuring the efficiency of electricity distribution companies were discussed.

Chapter 2 presents literature review were discussed that dealt with measuring the relative efficiency of electricity distribution companies by applying the data envelope analysis method. In these summaries, the methods used to measure efficiency, the number of companies (decision variables), their location, and the period for which data were collected were mentioned, as were the input and output variables.

Chapter 3 introduces definitions of some essential concepts DEA, Regression Models, Maximum likelihood estimation, and finally, the data and Turkish Electricity Distribution Companies was presents.

Chapter 4 presents the first stage of the study that was applied, which is related to estimating the relative efficiency of companies by defining the input and output variables used in the four models (CCR-I, CCR-O, BCC-I, BCC-O). After that, the efficiency values for all companies were extracted and classified in tables, and then the results were discussed.

Chapter 5 presents the second stage: calculating the quantile regression and Maximum likelihood estimation for the efficiencies that we got from stage one using the R program. Then, at last, we test the regression results using the goodness of fit and conclude the results.

2. LITERATURE REVIEW

It was the beginning of using the data envelope analysis method in 1978 with a doctoral student Edwardo Rhodes, who was working on an educational program in America to compare the performance of a group of struggling minority students in similar educational areas. Through a set of inputs and outputs without the availability of information on prices. To overcome this problem, the researcher and his supervisors formulated a model that was later known as the (CCR) model, an abbreviation of the Charnes-Cooper-Rhodes (Charnes, Cooper, & Rhodes, 1978).

Since then, articles, scientific research, and academic studies have begun to use this new method in conducting studies and comparing institutions, companies, and administrative, service, and production units that are similar in their inputs and outputs to evaluate their efficiency. Studies and research use this method in all fields such as (hospitals, universities, banks, agricultural production, factories, service sectors, military areas, etc.) The research and studies that used DEA until 2016 reached nearly 10,300 research (Emrouznejad & Yang, 2018).

(Hjalmarsson & Veiderpass, 1992) considered the first to use the data envelope analysis method for measuring the electrical distribution firms' operational efficiency. They compared productivity between 17 different ownership Swedish electricity distribution companies in different service areas from 1970 to 1986. They were using DEA and Malmquist productivity index in measuring the efficiency. The input variables are taken (the length of high voltage power lines (km), the length of low voltage power lines (km), hours worked (h) by all employees, and capacity of total transformers (kVA)) While their output variables were (the low voltage electricity that is delivered to customers (MWh), the high voltage electricity that is delivered to customers (MWh), the number of customers that received low voltage electricity, and the number of customers that received high voltage electricity). Their study concluded that the economies of density are a major contributor to rapid productivity growth. The results also showed no statistical differences were found in growth in productivity between organizations that have different ownership structures.

The first study related to evaluating the electrical distribution companies' efficiency in Turkey using the DEA method was done by (Bagdadioglu, Price, & Weyman-Jones, 1996). Their study compared the technical competence of the 66 public and four private electricity distribution companies for 1991 to examine the impact of privatization of

electricity distribution companies in Turkey. The results of this study showed higher levels of technical efficiency and measurement for private distribution companies. At the same time, this does not necessarily mean the success of private companies only in distributing electricity. The study showed the existence of public distribution institutions with high technical efficiency on a large scale. The study recommended the privatization of high-performance state-owned electricity distribution companies. The efficiency of Turkish electricity distribution companies was measured using DEA, and the following variables were adopted as input variables (Manpower, Transformer capacity MVA, Network size km, General expenses Turkish lira, Network losses MWh). And the output variables were (Customer number, Electricity supplied MWh, Maximum demand MW, Service area km²).

(Førsund & Kittelsen, 1998) used the technology of piecewise linear frontier, reflected by observing the best practice. It is specified how distribution utilities should be configured to accommodate their multi-output nature. They calculated the Malmquist index with its components and extracted the value shift in frontier technology and the change in efficiency from 1983 to 1989. They found that average productivity growth was roughly 2% annually, mainly attributed to the shifting to frontier technologies. However, outliers did not influence the results for non-outliers. The researchers applied the DEA and the Malmquist productivity index to data on 150 utilities DMUs of the Norwegian electricity distribution sector to gauge productivity growth. (Energy loss (MWh) and labor (h)) were represent the inputs (number of customers, total energy delivered (MWh), and distance index), were describe the outputs.

(Kumbhakar & Hjalmarsen, 1998) studied the production efficiency of the 300 Swedish retail electricity distribution companies with data spanning 1970-1990 using the DEA technique. Depending on (transformer capacity, labor) as inputs, and (low and high voltage electricity in MWhs received by the customers, kilometers of low and high voltage power lines, Numbers of low and high voltage customers) as outputs. The study aimed to know the extent of the impact of ownership of electricity distribution companies on the efficiency of municipal facilities owned by the private sector, municipal companies, and companies with mixed ownership, and three different methods were used to do so. The results show that private distribution companies are relatively more efficient, as reflected in economies of scale and technological advances. (Edvardsen & Førsund, 2001) have benchmarked using DEA and Malmquist productivity index to study a sample of large electricity distribution utilities from

Denmark, Finland, Norway, Sweden, and the Netherlands for the year 1997. The input variables were (labor, total operating expenses (TOM), the length of types of lines (air, underground, and sea), Loss MWh, the actual capital replacement value (RV)). In contrast, the output variables were (energy delivered and the number of customers). In addition, new indicators have been developed describing cross-country linkages between peers and their passive units and productivity measures between units from different countries.

(Chen, 2002) used the DEA to investigate and compare technical efficiency and cross-efficiency scores in the Taiwan electricity distribution sector. To identify the total efficiency and 'false standard' efficient districts to which electricity was distributed, they conducted a cross-efficiency assessment to compare with previous technical efficiency scores. By employing the false standard index (FSI), they could deduce that a greater magnitude results in increased benefit when shifting from peer-reviewing to self-reviewing. They were six utilities DMUs, and the data period was 1997 & 1998. the input variables were (a workforce of the electricity distribution region; total power lines (km); the overall transformer capacity (MVA); the size of the network system; and the output variables were (the number of low voltage electricity customers; the electricity supplied for low voltage (MWh); the number of high voltage electricity customers; the electricity supplied for high voltage (MWh)).

(Pacudan & De Guzman, 2002) used the DEA to analyze the productive efficiency of the electricity distribution utilities in the Philippines, where they simulate the impact of the energy efficiency plan on the productivity of the firms for the years 1996 - 2001. According to the study's findings, the most significant source of technical inefficiency in distribution utilities is scale inefficiency. Additionally, the study reveals that the industry's technical efficiency will improve if DSM electric power savings targets are met. In addition, system loss reduction targets have been shown to improve technical efficiency significantly. After examining the evidence, the paper concludes that energy efficiency policies, which are beneficial to the overall economy and the entire electricity supply industry, also increase productivity in the industry's distribution sector. The electricity distribution utilities DMUs were 15 utilities, and the inputs were (the loss of the system (GWh); the length of the circuit lines (km); the Number of Employees), and the outputs (the electricity sales (GWh); the number of customers; the Urban area served (km²)).

(Resende, 2002) used the DEA as a non-parametric methodology to evaluate the relative efficiency of the electricity distribution companies DMUs where it was 24 in Brazilian in 1997/98. the results refer to companies performing far less efficiently than what the efficiency frontier would recommend. After that, he determined what yardstick competition schemes are feasible, then discussed how complicated they would be to implement. The inputs were (the Transformer capacity (MVA); the network extension (km); the Number of Employees), and the outputs (the number of customers; the concession area (km²); the industrial sales of electric energy (MWh); the non-industrial sales of electric energy (MWh)).

(Chien, Lo, & Lin, 2003) conducted a study to measure the relative efficiency of 17 NAN-TOU electricity distribution centers affiliated to Taiwan Power Company (TPC) by applying the DEA method of the CCR and BCC models. They were used (total number of staff and general equipment (dollar)) as inputs, while (total number of customers, distribution network (km), and transformer capacity (kVA)) as outputs. The purpose of the study was to find alternatives to reorganizing service centers by measuring efficiency. The results showed that the proposed reorganization alternatives have better efficiency scores. Furthermore, based on the evaluations obtained from the application DEA, passive service centers were directed to improve their operational efficiency.

(Jamash, Nillesen, & Pollitt, 2003) examined how firms' strategic decisions can result in inefficient business decisions. The presentation of a survey of challenges faced by electricity regulators also took place. After that, they implemented the DEA technique with US utility data to analyze specific instances of strategic behavior and gauge the outcomes. Although regulation benchmarking can influence the “regulation game,” the subject has received limited attention. The results showed that gaming could have significant effects on the measured performance and profitability of firms. The electricity distribution utilities DMUs were five utilities operating in the northeast of the United States, and the data used was for 2000. inputs were (Operating Expenditure (OPEX)), and the outputs (the number of customers; the length of the network (km); units of electricity delivered).

(Pahwa, Feng, & Lubkeman, 2003) applied DEA, an approach for benchmarking the performance of the 50 largest (based on megawatt-hour sales) electric distribution utilities in the United States. The DMUs were 50 units, and the input variables were (operation and maintenance costs; systems losses; distribution line transformers; capital

additions costs; distribution lines) and output variables (retail customers; system peak load, retail sales). The study results included the efficiency of the utilities' performance. It showed large gaps in inefficient utilities' input and output values; they were classified based on sensitivity and a gap report. Thus, there is a comparison made as a peer-to-peer between efficient and inefficient units. Based on the results obtained, passive utilities Can design strategic plans to increase their performance of productivity. The data were for 1997.

(Estache, Rossi, & Ruzzier, 2004) used stochastic frontier analysis and data envelopment analysis to evaluate the efficiency of South America's major electricity distribution companies from 1994 - 2000. The two methods help regulators improve their positions in regulatory hearings by using simple checks to confirm their findings. The electricity distribution companies DMUs were 39 companies, and the inputs were (the Transformer capacity (MVA); the Distribution network (km); the Number of Employees; the Customer density; the Service area (km²); the Demand structure; GNP per capita), and the outputs (the electricity sales (GWh)).

(Giannakis, Jamasb, & Pollitt, 2005) assessed the reliability of the UK electricity distribution companies DMUs that were 14 companies between 1991/92 and 1998/99 and measured it by employing quality incorporated benchmarking. The data envelopment analysis technique was used to calculate the technical efficiency of the companies, while quality-incorporated Malmquist indices were utilized to estimate productivity change over time. Cost-efficient firms were found to have lower service quality than those that are less cost-efficient. Quality-based models outperform cost-only models in efficiency, but there is no significant correlation between the two. The findings demonstrate that improving service quality has contributed to the total productivity change in the sector. In addition, this study found that adding quality of service to regulatory benchmarking produces better results than using the cost as a metric only. The inputs were (the total expenditures (Totex); the operating expenditures (Opex)), and the outputs (the number of customers; the network length (km); the energy delivered (MWh)).

(Price, Weyman-Jones, & Bagdadioglu, 2006) studied the impact of the merger between the 82 Turkish electricity distribution firms and their transformation into 21 private distribution companies to assess the potential impact of these mergers and whether these mergers enhance efficiency. This was implemented through a comparison process of the actual efficiency levels of the distribution companies before merging them with the

proposed companies after the merger. They used DEA methodology to assess the potential effect of these mergers. The data used were from 1999 to 2003, using (number of employees, number of transformers, transformer capacity (MVA), network length (km), network losses (MWh)) as inputs, and (number of customers, electricity consumed (MWh), service area (km²)) as outputs. The results indicated the possibility of achieving significant efficiency gains from the proposed mergers.

(Hess & Cullmann, 2007) based on the information available to the researchers for 2001 about the 27 electricity distribution companies in Germany, the researchers used DEA and random border analysis (SFA) to analyze the material inputs and outputs within the framework of a function distance. They found that the electricity distribution companies in East Germany had higher technical efficiency than their counterparts in West Germany through various specifications of the experimental models. Furthermore, the researchers applied robustness analysis to the applied methods, data used, and model specifications. Their results confirmed a clear and significant difference in efficiency between the electricity distribution companies operating in Germany's eastern and western parts. The model inputs were (Total grid size (km), Labor), and the outputs were (Units sold to Customer (MWh)).

(Real, de la Fe, Iooty, de Almeida, & Pinto, 2008) evaluated the changes that happened in the productivity of the Brazilian electricity distribution sector applying DEA on 18 utilities DMUs from 1998 to 2005. The study analyzed the productivity variation of these distribution utilities in terms of scale efficiency, technical efficiency, and technical improvement. This research aims to help the understanding of the chief determinants of the progression of productivity, focusing on its association with the restructuring operation implemented in the 1990s. TFP index records an annually increasing percentage of 1.3% in the full term under analyzing for all utilities. The technical change was the chief element due to this evolution, with a growth rate of 2.1% yearly, while technical efficiency showed a negative performance of -0.8% annually. The outcomes generally demonstrate the incentives created in the improvement process do not appear to have led the utilities to perform more efficiently. The inputs were (the loss of the system (GWh); the length of the electricity grid (km); the Number of Employees; the Service Area (km²)). And the outputs (the number of customers; the electricity sales (GWh)).

(Bağdadıoğlu, 2009) applied DEA to study the efficiency of the 21 Turkish electricity distribution companies using 2004 data. In his study, he explained how the Energy

Market Regulatory Authority could encourage distribution companies to improve the quality of their services by following the principle of reward and punishment as a regulatory approach to them with companies Electricity distribution. According to the results obtained, 13 of the 21 distribution companies should be punished for poor service and eight companies with good service. Where the inputs are (Total Expenditures (TL) Number of Outages Interruption Duration (Hours)), and the outputs are (Number of Customers, Distributed Electricity (MWh) Network Length (Km)).

(Bağdadioğlu & Senyücel, 2010) aims to observe the importance of other variables such as (unlawful usage, the value of electricity distribution losses, and firm size) the importance of service quality criteria in the likely regulative design of electricity distribution in Turkey by using the Stochastic Frontier Analysis, DEA to the stable data from 2002 to 2007 for 20 distribution companies DMUs. The outcomes heavily indicate that, besides geographic stipulations and village density, the merger of service quality benchmarks in the efficiency model significantly influences the performance-based organization of electricity distribution. The inputs were (the total expenditures), and the outputs (the number of customers; the Energy Supplied (GWh)).

(Çelen, 2011) analyzed the relative technical efficiencies of the Turkish electricity distribution companies 21 DMUs from 2002 to 2009. He used six various model designations, all of them created two separate Stochastic Frontier Analysis (SFA) models. The results show the signs and significance levels of the coefficient guesses are very compatible and satisfying in all models. He also perceived consistency between the coefficient guesses of the different models, notwithstanding the differences in the estimated coefficient values. Furthermore, all model specifications prove the appearance of raising returns to scale and of clear technological progress with time in the market.

Additionally, all the inputs, but not the quality of the electricity served, are critical in reinforcing the electricity distribution companies' technical efficiency concerning the alternative specifications. Also, all the models displayed that the effects of inefficiency rather than random error effects are of fundamental importance in the electricity distribution market of Turkish. Finally, the efficiency evaluations of the alternative models, the chief conclusion exhibited by the study is that efficiency evaluations of the (George Edward Battese & Coelli, 1995) models are notably higher than these of the (George E Battese & Coelli, 1992) models. The efficiency calculation variances between Battese and Coelli's (1992&1995) models can be attributed to the environmental variables involved in Battese ve Coelli's (1995) models, which is

generally not in the range of the control of electricity distribution companies. The inputs were (the Transformer capacity (MVA); the Length of distribution line (km); the Number of Employees; the quality of electricity distribution), and the outputs (the number of customers; the Electricity delivered (MWh)).

(Düzgün, 2011) conducted an efficiency and productivity analysis of the 21 electricity distribution companies operating in Turkey. He applied the DEA method on the available data from 2007 to 2009 using the following variables as inputs (the number of employees, the length of the distribution line in km) and the following variables as outputs (Electricity delivered MWh, Number of customers person). Based on the results obtained by the researcher regarding the status of the companies, he made essential and different recommendations regarding the general policy of the electricity distribution companies.

(Çelen & Yalçın, 2012) suggested that the combined AHP / TOPSIS / DEA method for combining service quality and performance measurement was applied to Turkey's 21 electricity distribution companies. First, the relative importance levels for different quality indicators were determined using the FAHP method. Then they used the TOPSIS method to obtain the service quality variable, as this variable was used as an output when applying the DEA method to determine the efficiency performance of the electricity distribution companies. In this study, data for the period from 2002 to 2009 were used. When applying DEA, the input variables were (Number of employees Person, Length of distribution line (km), Transformer capacity (MVA)). In contrast, the output variables were (Quantity delivered (MWh), Number of customers Person, Quality of service %). The study concluded to highlight the importance of the combined methodology as it allows obtaining many quality measures at the same time instead of relying on only one quality measure.

(Yadav, Chauhan, Padhy, & Gupta, 2013) evaluated the relative performance of 29 Electricity Distribution Divisions (EDDs) of an Indian state, Uttarakhand, from 2005 to 2008 by applying the DEA method. The purpose of using this method is to improve the operational efficiency of EDD units, as Uttarakhand Power Corporation Limited (UPCL) has dismantled several major divisions into smaller divisions during this period. The study revealed the ineffectiveness of this process at the micro-level during the analysis period. Therefore, in the present work, a new reorganization model is proposed that differs from the dissociation model chosen by EDDs. The optimum scale for the partitioning process has been selected based on the 2007 competency analysis.

The average proficiency score for EDDs derived using the new proposed model has been compared with that of the original to verify this model. In the result, it was found that the overall efficiency of the proposed model is higher than the overall efficiency of the current system. To verify the robustness of the CCR results, therefore the reliability of EDDs was examined for efficacies for the same year. This study has provided a comprehensive assessment of UPCL to monitor and diagnose changes in the efficiency of EDDs. They used (Operating and Maintenance costs (Rs. Million), Number of employees) input variables, while (energy sold (Million units), number of customers, distribution line length (circuit kilometer), and Transformer capacity (kVA), Average duration of interruption per feeder (h)) as output variables.

(Dönmezçelik, 2014) measured the performance efficiency of electricity distribution companies using two models, the first based on a financial basis and the second on a technical basis. Data was employed for 21 electricity distribution companies between 2007 and 2011. DEA was applied using input-oriented CCR and BCC models. The variables (Cost-Based Model Unit, Expense TL, Area of Distribution Area km^2 , Number of customers) were used as inputs for the first model. In contrast, the outputs for the first model were (Cost-Based Model Unit, Loss and Leakage Amount MWh, Distribution Area Population Unit, Revenue TL, Distribution Area Area km^2 , Number of customers). The inputs of the second model were (Technical Based Model Unit, Number of Personnel Unit, Area of Distribution Area km^2 , Number of customers Unit, Line Length km). The outputs were (Technical Based Model Unit Supply Energy MWh Number of Failure Interruptions Number of Transformer Installed Power MVA). The result of the study was that the financial and technical performance of companies did not appear parallel over the years.

(Li, Li, & Zheng, 2014) measured the unified economic efficiency of the 24 electric power distribution companies in China from 2003 to 2010. The researchers focused on using the other options that were put forward to provide electric power from natural sources and reduce emissions from electric power generation companies. The researchers considered desirable outputs such as the amount of electricity sold and undesirable outcomes such as line loss in evaluating the performance of power distribution companies. They also created the USDEA model to calculate the standardized efficiency of companies by integrating the Standardized DEA model and the high-efficiency DEA model. The Uniform Efficiency DEA model can combine the desired and undesirable outputs in a single analytical structure. They compared the

various effective decision-making units DMUs through the highly efficient DEA model. The results obtained by the researchers showed that using standardized competence to evaluate energy supply companies would motivate them to pay more attention to social and environmental benefits as well as economic benefits. The researchers used (network length above 35 kV (km), transformers capacity above 35 kV (MVA), number of employees, cost of the main business) as inputs, while outputs were (Electric power supply amount (108 kWh), Power supply reliability (%), The quality of the voltage (%), Line loss (%)).

(Omrani, Beiragh, & Kaleibari, 2015) introduced an approach for estimating the relative efficiency of Iranian electricity distribution companies (37), representing the DMUs. They mixed bargaining game theory, principal component analysis (PCA), and DEA to gain more comprehensive realistic outcomes with more extensive resolution power. Sometimes, the number of DMUs below evaluation is not big enough compared to the total number of inputs and outputs. To throw this problem and decrease the number of variables, the PCA technique was joined with the regular DEA model. Then, the bargaining game model was merged with the PCA–DEA model to distinguish among the DMUs. The results show the abilities of the suggested approach to assessing the DMUs in a competitive environment. The inputs were (the Area (km²); the Terrestrial network length (km); the number of employees; the Aerial network length (km); the Transformer capacity (MVA); the Number of Transformers). And the outputs were (the number of other customers; the Number of household customers; the Household Energy consumption; the Energy delivery (MW h); the Industrial Energy consumption; the Number of lights of Street lighting; the Number of industrial customers; the Energy consumption of other customers). They used the data of 2010.

(Çelen, 2016) analyzed the relative technical efficiencies of Turkish electricity distribution companies 21 DMUs from 2002 to 2009. He produced three different model specifications using the Stochastic Frontier Analysis (SFA) model to execute this aim. The results showed that the signs and significance levels of the coefficient evaluations are very regular and acceptable in all models and all of the specifications. Additionally, all the inputs, except the quality of the electricity served, are critical in reinforcing the electricity distribution companies' technical efficiency concerning the alternative specifications. The inputs were (the Transformer capacity (MVA); the Length of distribution line (km); the Number of Employees; the Outage hours per customer hour/cust), and the outputs (the number of customers; the Electricity delivered (MWh)).

(Hemapala & Neelawala, 2016) applied the DEA method, which uses a linear programming approach to find out The relative efficiency scores so it can be used later to calculate the efficiency factor (X-factor), a segment of the revenue control formula. This research focuses on achieving a proper benchmarking methodology by studying prominent benchmarking techniques utilized in the global regulatory regime and analyzing their applicability to the Sri Lankan circumstances. There are only five distribution licenses are operating. There are only five electricity distribution companies DMUs that have licenses operating in Sri Lanka. The input variables were (the Energy sales/ operating expenditures; the Number of consumers/ operating expenditures; Energy sales/employees; Number of consumers/employees) and the outputs (the Energy delivered; the number of new connections provided). The data were from 2006 to 2011. (Meher & Sahu, 2016) were calculated the relative efficiency of the 40 electricity distribution companies DMUs distributed over 17 states in India for the year 2012-2013 using the Frontier tool, viz. Data envelope analysis. The model with constant returns to scale was applied to measure the relative efficiency of a different sample of depleted uranium. The Input Orientation Scale was used to obtain the efficiency scores. The results indicated that there was inefficiency in 29 out of 40 distribution companies. Ineffective companies can become effective companies by comparing them with the most efficient companies. To get the same output, these firms need to reduce their use of inputs until they reach the scale of the most productive scale. Regulators need to give special consideration to enhancing the efficiency of inefficient firms by exploring alternative methods such as incentive-based regulation. The input variables were (the net energy (MWh); operating expenditures; capital expenditures) and the outputs (the distributed energy (MWh); the number of customers).

(Goerlich & Ruehrnoessl, 2017) outlined the prevailing Austrian regulative regime, conducted a DEA-based analysis with different model specifications, analyzed the second stage follows, carried out a sensitivity analysis concerning the price of quality, and fixed the shadow price for the quality. They concluded that capital costs (book values vs. annuities) have a much more significant effect on efficiency scores than the inclusion of quality (interruption costs). However, shadow prices maybe not manage to a social optimum if the existing quality level is previously too low or too high. Therefore, it is preferable to treat quality as an integral piece of the input cost base, i.e., that will be done by appending interruption costs to network total costs (TOTEX) and not as a separate input. This should be made even if global examination statistics

intimate that the inclusion of quality has a non-significant result on the mean of efficiency degrees. The Austrian electricity distribution companies DMUs were 38 companies. The input variables were (the total expenditures (Peak load)) and the outputs (the transformed area-weighted connection density for the low voltage level; the transformed area-weighted connection density for the medium). The data were for 2007 – 2011.

(Zorzo, Diehl, Venturini, & Zambon, 2017) set out to investigate whether there is a connection between attention to innovation and the level of relative economic efficiency; they used data about 20 Brazilian private energy distribution firms DMUs from 2010 to 2013. They applied DEA to estimate the relative efficiency scores using Frontier Analyst software. The significant results of the innovation scale indicate a decrease in focus on innovation from companies surveyed when there is no meaningful correlation between the economic efficiency scores and the innovation scores. The input variables were (the Operational expenses; the Operational costs), and the outputs (the Consumer Units; the network length (km); the Energy Sold (GWh); the Concession area (km²)).

(Bobde & Tanaka, 2018) conducted a two-stage data envelopment analysis with a bootstrap estimation to examine the efficiency of electricity distribution utilities in India using bias-corrected efficiency estimates, which were created using data from 2005 to 2012. this was represented in the first stage and then regressed on external environmental variables in the second stage. At the begun the positive impacts of customer structure and population density on the overall efficiency of utilities were denoted. The second thing they discovered was that the public utilities in the electric distribution sector of India offer efficiency advantages. However, in densely populated areas, public utilities are less efficient than private ownership. Finally, they have discovered that government subsidies have a negative impact on utility efficiency. The electricity distribution utilities DMUs were 13 utilities, where Six utilities are state-owned, while seven are privately owned. The input variables were (Transformer capacity (MVA); Distribution line length (km); the Number of Employees; Total assets (inflation-adjusted)), and the outputs (the number of customers; Electricity delivered (GWh)).

(Ganhadeiro, Christo, Meza, Costa, & Souza, 2018) presented an alternative method for evaluating the efficiency of Brazil's 32 electricity distribution companies. The proposed

model uses the Network DEA model with the network dimension as an intermediate variable and uses Kohonen self-organizing maps (SOM) to overcome and correct the difficulties and obstacles caused by environmental variables. To access the environmental variables affecting efficiency, they used factor analysis to reduce the model's dimensions. The efficiency obtained from DEA represented the dependent variable, while the four factors obtained from factor analysis represented the independent variables in the multiple regression equation. SOM established four groups in which the environment and efficiency were distributed to reach the best correction for factor X (which represents the evolution of efficiency in the price cap regulation model), which can be done with a fixed margin for comparison within each group. The researchers expected that using this model would reduce the process of questioning distributors for evaluation. The researchers used (operational expenses (OPEX)) as input, and the output was (Number of consumers, consumption MWh). The data of Research-based on 2012.

(Martins, Diehl, Rempel, & Tagliari, 2018) analyzed the relative technical efficiency of Brazilian electric distribution companies, which was (18) DMUs for the year 2012. This research including a quantitative procedure based on the application of Data Envelopment Analysis. Seven of the eighteen companies had a score of 100% relative technical efficiency. The efficient companies are diffused across Brazil, with a higher intensity in the Southeast. The Municipal Human Development Index, the extent of the served area, the size of the distribution network, and Population density do not explain the achievement of efficiency factors. The input variables were (the total of all assets of a company; tangible assets; the Number of Employees; the company's operating profit, disregarding financial income or expense), and the outputs (Profit for the Period; Net Revenues).

(B. Korkmaz, 2019) analyzed the 21 electricity distribution companies in Turkey to establish a performance evaluation system based on a hierarchical analytical process and compare the results of the two methods when repeating the previous work using the DEA method with recent data. In her study, data on electricity distribution companies for the year 2018 was used. The inputs of the first model were ((Cost-Based Model) Expense TL, Area of Distribution Area km^2 , Number of Customers), and its outputs (Cost-Based Model Loss Theft Amount MWh, Distribution Area Population Number, Revenue TL, Distribution Area km^2 , Number of Customers). The inputs of the second model were ((Technical Based Model) Number of Personnel Number, Area of

Distribution Area km^2 , Number of Customers, Line Length km), and its outputs (Technical Based Model Supplied energy MWh, Number of Fault Interruptions Units, Transformer Installed Power MVA).

(Petridis, Ünsal, Dey, & Örkücü, 2019) used Network DEA technology because of multiple production stages regarding electric power generation and supply procedures. The directional distance function is also integrated into Network DEA technology. They applied it to the 21 electricity distribution companies in Turkey through the data available to them for the year 2011. The inputs of the first stage were (Number of Staff, Net Consumption (MWh), Number of transformers, Length of Cables (km), Installed Capacity (MVA)). Its outputs were (Energy supply (MWh), Annual faults and interruptions (num), Energy losses (MWh)). While the inputs of the second stage were (Energy supply (MWh)), and its outputs were (Number of Customers, Number of Towns/Villages). The researchers' goal of the proposed model was to evaluate the profit efficiency of electricity distribution companies, taking into account the expansion costs of additional power supplies. The results are presented based on measures of radial efficiency and profitability.

(Koçak & Boran, 2019) used the DEA method by applying the CCR model and the BCC model to the data they have for 2016 on the quantities of electricity consumption in the 81 Turkish provinces to determine the effectiveness of electricity consumption in these provinces through a procedure a comparison of the amount of electricity consumed in each governorate with the type of consumer. The input variables were (Consumption based on consumers (MWh), (1. Lighting, 2.Residential, 3.Industry, 4.Trade))and output variables (Number of Consumers).

(Güler, Kandemir, & Açikkalp, 2020) studied the relative efficiency of the 21 Turkish electricity distribution companies through their data for the year 2019 by using DEA. Four DEA models have been applied: input-output-oriented CCR and input-output-oriented BCC models. The input variables were (Loss Leakage Rate (%), Service Area (km^2), Maximum Demand (Person)), and the output variables were (Number of customers (Person), Electricity Consumption Amount (kWh)).

(Yenioğlu & Toklu), 2020 measured the efficiency of the performance of the 21 electricity distribution companies in Turkey using the DEA method, where the input-oriented and output-oriented BCC models were selected. The researchers used two types of data when applying. The first type is actual data recorded about the electricity distribution companies from 2011 to 2016, and the second type is stochastic data that

were included as input and output variables in DEA. According to the efficiency results of the actual and stochastic models, the practical and passive electricity distribution companies were identified. They used (Operating Expenditure (OPEX), Transformer Power: MW of transformer installed power, Peak Load: Electricity consumption) as input variables, and the output variables were (Number of customers, Amount of Energy Entered into the Distribution System).

(Oğuz & Mustafa), 2020 presented a study on the relative efficiency of the 21 electricity distribution companies in Turkey for 2013-2018. They identified and modeled the factors that lead to inefficiency. The study analysis method had two stages. In the first stage, the non-parametric method DEA was used to calculate The relative efficiency of companies. For evaluating the resistance of these competencies, it was tested by the Bootstrap test method. In the second stage of the analysis, the efficiency values obtained from the first stage were used as dependent variables. The internal/external variables that lead to inefficiency were identified using Simar Wilson's methodology. The research results indicated that expanding the geographical area served by the single distribution company and increasing its investments in the service field led to increased efficiency. In contrast, the increase in the capacity of transformers and the increase in the rates of energy loss and leakage led to a decrease in the efficiency of the electricity distribution companies. The input variables for the first model were (Length of lines (km), Number of Transformers, Number of Employees, Number of customers). As for output variables, they were (Number of Incidents, Consumption Energy(MWh)). As for the second model, its inputs were (Number of Customers, the Urban area served (km²), Number of Employees, Number of Transformers, Length of lines (km)), and its outputs were (Loss Leakage Rate).

3. DATA ENVELOPMENT ANALYSIS AND REGRESSION MODELS

3.1. The First Stage: Data Envelopment Analysis

is a nonparametric valuable tool that uses linear programming in the evaluation of relative efficiency of decision-making units (DMUs) with common inputs and outputs. The first use of DEA was by (Charnes et al., 1978).

Without any presuppositions or assumption about the functional structure of the frontier, the DEA estimates the efficiency of DMUs based on many variables of input and output concurrently. In addition, the DEA method does not need previous assumptions of the relationship between input and output variables, and they can have too far different units. There are various versions of DEA based on its characteristics. Two popular features of the DEA form are the structure of its returns to scale and orientations in efficiency analysis. (Dalfard, Sohrabian, Najafabadi, & Alvani, 2012).

The efficiency of any unit or utility Consisting of two segments:

1. Technical efficiency: It refers to a company's ability to generate the greatest amount of output from a given set of inputs.
2. Allocative efficiency: It refers to the ability of a company to use the inputs in the best proportions, according to their respective prices.

In DEA, the performance or efficiency of DMUs were evaluated in two methods:

1. Input-oriented model: It attempts to determine whether the DMU can reduce its current input while still producing the same number of outputs as previously determined.
2. Output-oriented model: With the current input level, it attempts to determine whether the DMU can increase its current output. (Kumar et al., 2017).

3.1.1. Efficient frontier

Efficient Frontier: The line attaching the most efficient points is the efficient frontier named the 'frontier line.' Efficient frontier envelopes other data points; that's why it is called 'data envelopment analysis.'

- ❖ The frontier line denotes how well the unit performs when compared to other units.

- ❖ Other units can be compared based on the difference between the points on the frontier line. When compared to the efficient frontier, the other units' efficiency is defined.
- ❖ This efficient frontier serves as a standard of comparison. (Kumar et al., 2017).

We will take an example to illustrate the DEA technique; let us assume that we have five companies using two inputs, t_1 and t_2 , to produce one output, f . If it is being solved by linear programming, we will get a piece-wise linear frontier ZZ' , as is shown in Figure. Companies lying on the frontier (J, K, and L) are completely efficient, while companies that lie above the frontier (M and N) are inefficient.

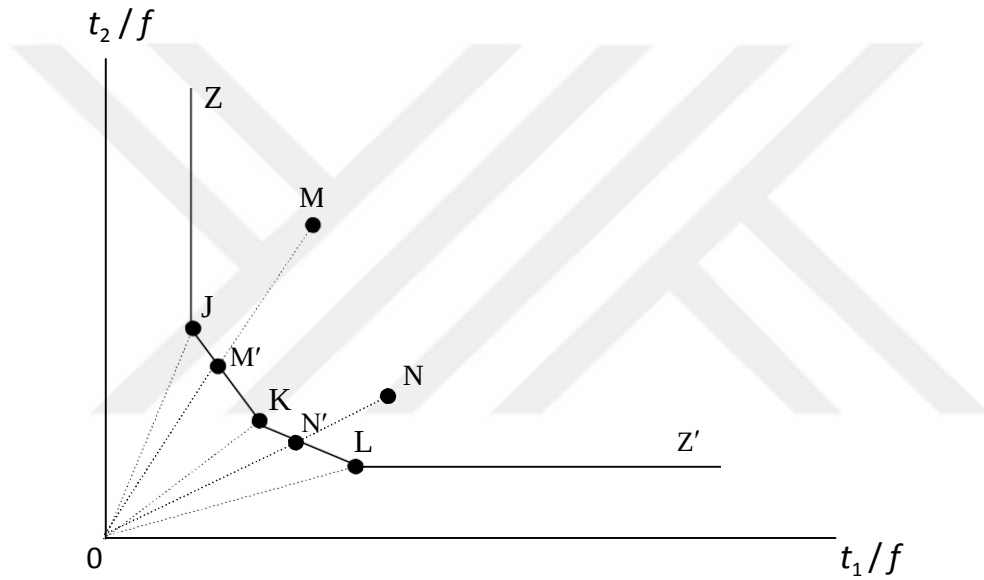


Figure 3.1. Input-Oriented performance measurement with DEA

The technical efficiency of company M is obtained by the proportion OM' / OM . We should remark that M' in Figure 3.1. does not express the company. Point M' represents the location where company A would obtain if it could be done fully efficiently by radially decreasing its use of both inputs.

As explained, the input-oriented DEA method evaluates the efficiency degrees by decreasing the input usage radially. In this method, moving the company towards the most suitable practice frontier is suggested by all other notes. (Çelen, 2011).

3.1.2. Data envelopment analysis models

According to the structure of returns to scale, there are two types: the first constant returns to scale CRS or CCR (Charnes et al., 1978). And the second variable returns to scale VRS or BCC (Banker, 1984). In the CRS issuance, it is supposed that the increase in the quantity of inputs would guide to a proportional increasing in the quantity of outputs. On the other hand, in the VRS issuance, the quantity of outputs is considered to increase less or more proportionally from the increase in the quantity of inputs. Therefore, a restriction imposed by the CRS issuance is even more constraining than the VRS and, as a result, produces fewer efficient units and lower efficiency scores for all DMUs. Because the CRS is a case of the VRS model, this is why. (Dalfard et al., 2012). In the orientations of the efficiency analysis, there are two popular directions. The first is input-oriented models: where DMUs are assumed to give specific quantities of outputs with the smallest possible quantities of inputs. The second is Output-oriented models: where DMUs are assumed to provide the highest possible outputs with particular amounts of inputs. (CHARNES & COOPER, 1994).

3.1.2.1. Charnes-Cooper-Rhodes model or constant returns to scale

Suppose n DMUs with m inputs and k outputs; the BCC model related to DMU_p where θ_p indicates the efficiency score of DMU_p , x_{ij} indicates the i^{th} input of the j^{th} DMU, y_{rj} indicates the r^{th} output of the j^{th} DMU and λ_j means the weight of the j^{th} DMU. (Banker, 1984) (Dalfard et al., 2012).

$$\text{Min } \theta_p$$

s.t.

$$\sum_{j=1}^n \lambda_j x_{ij} \leq \theta_p x_{ip}$$

$$\sum_{j=1}^n \lambda_j y_{rj} \geq y_{rp}$$

$$\lambda_j \geq 0, j = 1 \dots n, i = 1 \dots m, r = 1 \dots k$$

A. Input-oriented Charnes-Cooper-Rhodes model CCR – I

This is the input-oriented version (dual problem) of the most basic DEA model (Charnes et al., 1978) (Argyriou & Sifaleras, 2013).

$$\begin{aligned} \min z &= \theta \\ \theta, \lambda & \\ \text{s.t. } \theta x_o - X\lambda &\geq 0 \\ Y\lambda &\geq y_o \\ \lambda &\geq 0 \end{aligned}$$

The efficiency score is denoted by a scalar θ

B. Output-oriented Charnes-Cooper-Rhodes model CCR – o

The output-oriented version is formulated as follows:

$$\begin{aligned} \max z &= \eta \\ \eta, \mu & \\ \text{s.t. } & \\ x_o - X\mu &\geq 0 \\ \eta y_o - Y\mu &\leq 0 \\ \mu &\geq 0 \end{aligned}$$

The efficiency score is denoted by a scalar η

3.1.2.2. Banker-Charnes-Cooper model or variable returns to scale

Suppose n DMUs with m inputs and k outputs; the BCC model related to DMU_p where θ_p indicates the efficiency score of DMU_p , x_{ij} indicates the i^{th} input of the j^{th} DMU, y_{rj} indicates the r^{th} output of the j^{th} DMU and λ_j means the weight of the j^{th} DMU. (Banker, 1984) (Dalfard et al., 2012).

$$\text{Min } \theta_p$$

$$\begin{aligned} \text{s.t. } & \\ \sum_{j=1}^n \lambda_j x_{ij} &\leq \theta_p x_{ip} \\ \sum_{j=1}^n \lambda_j y_{rj} &\geq y_{rp} \\ \sum_{j=1}^n \lambda_j &= 1 \\ \lambda_j &\geq 0, j = 1 \dots n, i = 1 \dots m, r = 1 \dots k \end{aligned}$$

A. Input-oriented Banker-Charnes-Cooper model

The input-oriented version of the classic DEA model differs from the CCR-I model only in the addition of the convexity condition (e is the unity vector) (Banker, 1984) (Argyriou & Sifaleras, 2013).

$$\begin{aligned}
 \min z &= \theta \\
 \theta, \lambda & \\
 \text{s.t.} & \\
 \theta x_o - X\lambda &\geq 0 \\
 Y\lambda &\geq y_o \\
 e\lambda &= 1 \\
 \lambda &\geq 0
 \end{aligned}$$

B. Output-oriented Banker-Charnes-Cooper model

The output-oriented version is formulated as follows:

$$\begin{aligned}
 \max z &= \eta \\
 \eta, \lambda & \\
 \text{s.t.} & \\
 X\lambda &\leq x_o \\
 \eta y_o - Y\lambda &\leq 0 \\
 e\lambda &= 1 \\
 \lambda &\geq 0
 \end{aligned}$$

3.2. The Second Stage: Regression Models

3.2.1. An alternative quantile regression model

In this sub-section, we introduce an alternative quantile regression based on the UGHN distribution and it is used to construct a new quantile regression analysis.

(M. Ç. Korkmaz, 2020) has introduced UGHN distribution via a transformation $\exp(X)$ of the generalized half-normal (GHN) distribution random variable (Cooray & Ananda, 2008). Here we introduce a new unit distribution by using transformation $X / (1 + X)$ of the GHN distribution random variable. Let the random variable X follows a GHN distribution with probability density function (pdf) and cumulative distribution function (cdf)

$$f_{GHN}(x, \alpha, \beta) = 2\alpha x^{\alpha-1} \beta^{-\alpha} \phi\left[\left(\frac{x}{\beta}\right)^{\alpha}\right]$$

and

$$F_{GHN}(x, \alpha, \beta) = 2\Phi\left[\left(\frac{x}{\beta}\right)^{\alpha}\right] - 1 = 1 - 2\Phi\left[-\left(\frac{x}{\beta}\right)^{\alpha}\right],$$

respectively, where $x > 0$, $\alpha, \beta > 0$, $\phi[\cdot]$ is the pdf of standard normal distribution and $\Phi[\cdot]$ is the cdf of standard normal distribution.

Let X be a GHN random variable, then $Y = X / (1 + X)$ has follows UGHN random variable with pdf and cdf, respectively,

$$f(y, \alpha, \beta) = \frac{2\alpha y^{\alpha-1}}{(1-y)^{\alpha+1} \beta^{\alpha}} \phi\left[\left(\frac{y}{(1-y)\beta}\right)^{\alpha}\right],$$

and

$$F(y, \alpha, \beta) = 2\Phi\left[\left(\frac{y}{(1-y)\beta}\right)^{\alpha}\right] - 1, \quad (2)$$

where $0 < y < 1$, $\alpha > 0, \beta > 0$ are the shape parameters. The distribution with cdf (2) is denoted by $UGHN(\alpha, \beta)$. It is noticed that the quantile function of the UGHN distribution can be represented by

$$y_u(\alpha, \beta) = \frac{\beta \left\{ \Phi^{-1}\left(\frac{u+1}{2}\right) \right\}^{1/\alpha}}{1 + \beta \left\{ \Phi^{-1}\left(\frac{u+1}{2}\right) \right\}^{1/\alpha}},$$

where $0 < u < 1$ and $\Phi^{-1}(\cdot)$ is the inverse function of the cdf of the standard normal distribution.

For the quantile regression analysis, the pdf of the UGHN distribution can be given with a re-parameterization based on its quantile function. Let $\mu = y_u(\alpha, \beta)$ and

$\beta = \frac{\mu}{(1-\mu)\left\{\Phi^{-1}\left(\frac{u+1}{2}\right)\right\}^{1/\alpha}}$. Then, the cdf and pdf of the re-parameterized UGHN

distribution are given by

$$G(y, \alpha, \mu) = 2\Phi\left[\left(\frac{y(1-\mu)}{\mu(1-y)}\right)^\alpha \Phi^{-1}\left(\frac{u+1}{2}\right)\right] - 1$$

and

$$g(y, \alpha, \mu) = \frac{2\alpha y^{\alpha-1}(1-\mu)^\alpha \Phi^{-1}\left(\frac{u+1}{2}\right)}{(1-y)^{\alpha+1} \mu^\alpha} \phi\left[\left(\frac{y(1-\mu)}{\mu(1-y)}\right)^\alpha \Phi^{-1}\left(\frac{u+1}{2}\right)\right], \quad (3)$$

respectively, where $\alpha > 0$ is the shape parameter, the parameter $\mu \in (0,1)$ represents the quantile parameter and u is given or known. After here, the random variable Y with pdf (3) is denoted by $Y \sim UGHN(\alpha, \mu, u)$.

Let $y_1, y_2, \dots, y_n$ such that y_i is a realization of $Y_i \sim UGHN(\alpha, \mu_i, u)$ for $i=1, \dots, n$, where μ_i and α are the unknown parameters. Hence, the proposed quantile regression model is defined as

$$g(\mu_i) = \mathbf{x}_i \boldsymbol{\gamma}^T, \quad i=1, \dots, n,$$

where $\boldsymbol{\gamma} = (\gamma_0, \gamma_1, \gamma_2, \dots, \gamma_p)^T$ and $\mathbf{x}_i = (1, x_{i1}, x_{i2}, x_{i3}, \dots, x_{ip})$ are the unknown regression parameter vector and known i^{th} vector of the covariates. The function $g(z)$ is a link function used to connect the covariates to the conditional quantile of the response variable. If, when the parameter $u=0.5$, the covariates are linked to a median of the response variable. Since the UGHN distribution is a probability distribution on the (0,1) interval, the logit-link function, which is given by

$$g(\mu_i) = \log\left(\frac{\mu_i}{1-\mu_i}\right), \quad i=1, 2, \dots, n,$$

can be used for the connection. It is noticed that the probit and log-log link functions can also be used for linking to quantiles of the response variable.

3.2.2. Maximum likelihood estimation method for the model parameters

In this section, the maximum likelihood estimation of parameters of the UGHN quantile regression model is discussed. Let us consider the following logit link function:

$$g(\mu_i) = \log\left(\frac{\mu_i}{1-\mu_i}\right) = \mathbf{x}_i \boldsymbol{\gamma}^T, \quad i = 1, \dots, n. \quad (4)$$

Using (4), the following relation is obtained

$$\mu_i = \frac{\exp(\mathbf{x}_i \boldsymbol{\gamma}^T)}{1 + \exp(\mathbf{x}_i \boldsymbol{\gamma}^T)}, \quad i = 1, \dots, n.$$

Let $Y_1, Y_2, \dots, Y_n$ be a random sample of size n from the $UGHN(\alpha, \mu_i, u)$ distribution with the observed values $y_1, y_2, \dots, y_n$ for $i = 1, \dots, n$. Then the log-likelihood function is given by

$$\begin{aligned} \ell(\boldsymbol{\Theta}) = & n \log(2\alpha) + (\alpha - 1) \sum_{i=1}^n \log(y_i) - (\alpha + 1) \sum_{i=1}^n \log(1 - y_i) + \alpha \sum_{i=1}^n \log(1 - \mu_i) \\ & - \alpha \sum_{i=1}^n \log(\mu_i) + n \log\left(\Phi^{-1}\left(\frac{u+1}{2}\right)\right) + \sum_{i=1}^n \log\left\{\phi\left[\left(\frac{y_i(1-\mu_i)}{\mu_i(1-y_i)}\right)^\alpha \Phi^{-1}\left(\frac{u+1}{2}\right)\right]\right\} \end{aligned} \quad (5)$$

where $\boldsymbol{\Theta} = (\alpha, \boldsymbol{\gamma})$ is the unknown parameter vector. The MLEs of $\boldsymbol{\Theta}$, say $\hat{\boldsymbol{\Theta}} = (\hat{\alpha}, \hat{\boldsymbol{\gamma}})$, is obtained by maximizing $\ell(\boldsymbol{\Theta})$ with respect to $\boldsymbol{\Theta}$. In R, the **maxLik** function (Henningsen & Toomet, 2011) with Nelder-Mead optimization method can be used for maximization.

Based on the regularity conditions, the asymptotic distribution of $(\hat{\boldsymbol{\Theta}} - \boldsymbol{\Theta})$ is multivariate normal $N_{p+1}(0, J^{-1})$, where J^{-1} is the inverse of the expected information matrix. In practice, it is generally used the $(p+1) \times (p+1)$ observed information matrix instead of J . The elements of this observed information matrix are calculated numerically by **optim** or **maxLik** functions in R. It is noticed that, the **maxLik** function in R also derives asymptotic standard errors. The gradients correspondences to likelihood (5) are found to be

$$\frac{\partial \ell(\Theta)}{\partial \gamma_0} = \alpha \sum_{i=1}^n \left\{ \left(\frac{y_i}{(1-y_i) \exp(\mathbf{x}_i \gamma) \left(\Phi^{-1} \left(\frac{u+1}{2} \right) \right)^{\frac{1}{\alpha}}} \right)^{2\alpha} - 1 \right\},$$

$$\frac{\partial \ell(\Theta)}{\partial \gamma_j} = \alpha \sum_{i=1}^n x_{ij} \left\{ \left(\frac{y_i}{(1-y_i) \exp(\mathbf{x}_i \gamma) \left(\Phi^{-1} \left(\frac{u+1}{2} \right) \right)^{\frac{1}{\alpha}}} \right)^{2\alpha} - 1 \right\}, j = 1, 2, \dots, p$$

$$\begin{aligned} \frac{\partial \ell(\Theta)}{\partial \alpha} = & \sum_{i=1}^n \frac{\left(-\log \left(\frac{y_i}{(1-y_i) \exp(\mathbf{x}_i \gamma) \left(\Phi^{-1} \left(\frac{u+1}{2} \right) \right)^{\frac{1}{\alpha}}} \right) \alpha - \Phi^{-1} \left(\frac{u+1}{2} \right) \right) \left(\frac{y_i}{(1-y_i) \exp(\mathbf{x}_i \gamma) \left(\Phi^{-1} \left(\frac{u+1}{2} \right) \right)^{\frac{1}{\alpha}}} \right)^{2\alpha}}{\alpha} \\ & + \frac{1 + \alpha \log \left(\frac{y_i}{1-y_i} \right) - \log \left(\exp(\mathbf{x}_i \gamma) \left(\Phi^{-1} \left(\frac{u+1}{2} \right) \right)^{\frac{1}{\alpha}} \right) \alpha + \Phi^{-1} \left(\frac{u+1}{2} \right)}{\alpha}. \end{aligned}$$

3.3. Data Description

In this study, we dealt with the electricity distribution companies located in Turkey, which number (21) private companies, as these companies distribute electricity to all (81) provinces of Turkey. They are distributed as regions to these companies, as shown in Table 3.1. and Figure 3.1. Actual data from 2007 to 2019 were obtained from the annual statistical reports issued by the Turkish Electricity Distribution Corporation (TEDAŞ), one of the Turkish Ministry of Electricity and Natural Resources companies (Annual Reports, 2007-2019). This company undertakes the task of following up and supervising the private electricity distribution companies.

Table 3.1. Electricity distribution companies and their regions.

Rank	Company	Electricity Distribution Regions and Provinces Covered by Region
1	Dicle EDAŞ	Diyarbakır, Mardin, Siirt, Şanlıurfa, Batman, Şırnak
2	Vangözü EDAŞ	Bitlis, Hakkari, Muş, Van
3	Aras EDAŞ	Ağrı, Erzincan, Erzurum, Kars, Bayburt, Ardahan, Iğdır
4	Çoruh EDAŞ	Artvin, Giresun, Gümüşhane, Rize, Trabzon
5	Fırat EDAŞ	Bingöl, Elazığ, Malatya, Tunceli
6	Çamlıbel EDAŞ	Sivas, Tokat, Yozgat
7	Toroslar EDAŞ	Adana, Mersin, Osmaniye, Hatay, Gaziantep, Kilis
8	Meram EDAŞ	Kırşehir, Nevşehir, Niğde, Aksaray, Konya, Karaman
9	Başkent EDAŞ	Ankara, Bartın, Çankırı, Karabük, Kastamonu, Kırıkkale, Zonguldak
10	Akdeniz EDAŞ	Antalya, Burdur, Isparta
11	Gediz EDAŞ	İzmir, Manisa
12	Uludağ EDAŞ	Balıkesir, Bursa, Çanakkale, Yalova
13	Trakya EDAŞ	Tekirdağ, Kırklareli, Edirne
14	AYEDAŞ	İstanbul (Anadolu Yakası)
15	Sakarya EDAŞ	Sakarya, Bolu, Düzce, Kocaeli
16	Osmangazi EDAŞ	Afyon, Bilecik, Eskişehir, Kütahya, Uşak
17	Boğaziçi EDAŞ	İstanbul (Avrupa Yakası)
18	KCETAŞ	Kayseri (Sivas ilinin bazı köyleri de lisans bölgesindedir)
19	Aydem EDAŞ	Aydın, Denizli, Muğla
20	Akedaş EDAŞ	Adıyaman, Kahramanmaraş
21	Yeşilirmak EDAŞ	Amasya, Çorum, Ordu, Samsun, Sinop

**Figure 3.2.** A map of Turkey on which the electricity distribution companies and their regions are distributed.

Source: (ENERGY MARKET 365).

As a result, we collected data on 15 variables for each company for 13 years, as these data are applied in data envelopment analysis and then in regression analysis. The variables that were collected are shown in Table 3.2.

Table 3.2. The variables that were collected about electricity distribution companies.

Variables				
Number of Villages & Towns (NO)	Population Number (NO)	Number of Customers (NO)	Number of Employees (Labour) (NO)	Transformer Installed Power (MVA)
Number of poles (NO)	Number of Streets lighting (NO)	Gross Electricity Generation (MWh)	Length of the Grid in (aerial, cable lines) (km)	Energy Loss (MWh)
Number of Incidents (NO)	Number of Transformers (NO)	Net Consumption Energy (MWh)	Urban area served (km²)	Investment Amount (tl)

4. THE FIRST STAGE: DATA ENVELOPMENT ANALYSIS APPLICATION

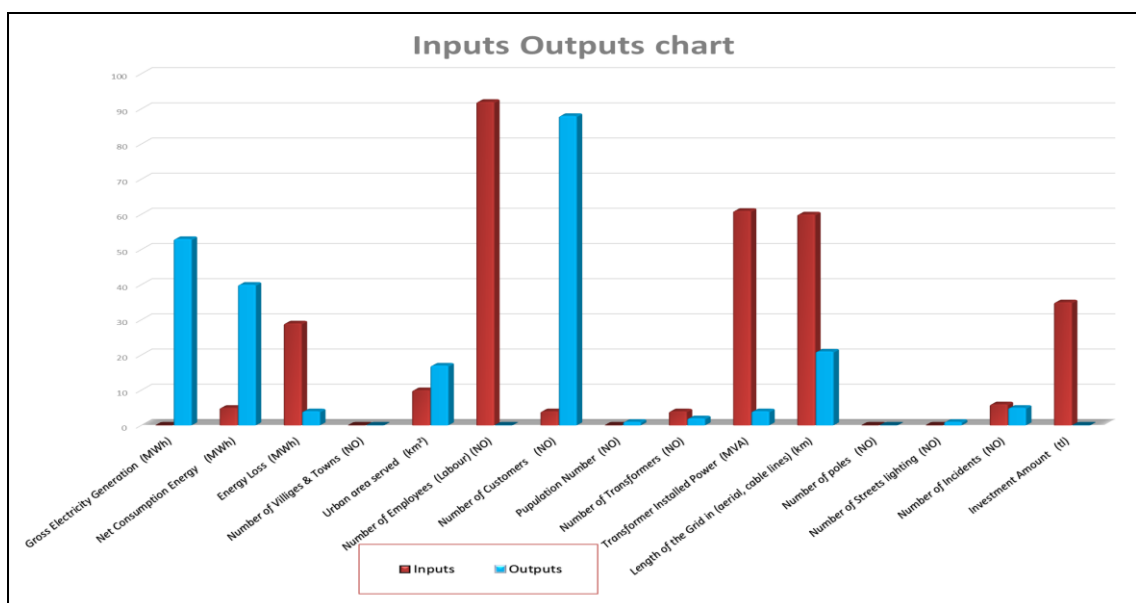
4.1. Variables of Data Envelopment Analysis

The efficiency problem of the electricity distribution companies is manifested in reducing energy losses resulting from loss and leakage, as the total energy supplied is the sum of net consumption with the lost energy. The loss of power is considered a usual case shared by all distribution companies. Still, it varies and varies in terms of the amount of lost energy and its percentage from one company to another. All distribution companies have similar data on this, and power loss is a very common variable for this type of efficiency study. The number of customers is also one of the most common output variables to measure the service efficiency of electricity distribution companies as it reflects the total population served by the distribution companies within their region. In addition, this data also includes information on the number of towns and villages that the distribution company serves. The data also had the number of employees working in each company, which is an essential variable in measuring service efficiency and one of the commonly used data to measure the efficiency of electricity distribution companies in the literature. In addition, we found that cable lengths are also generally preferred data as an input variable for electricity distribution companies. Installed power is one of the most commonly used input variables to measure the service efficiency of electrical distribution companies.

The annual investment amount of companies is also essential to measure the efficiency of companies. As finally, in this study, the number of staff, installed power (MVA), length of cables (km), energy loss (MWh), and the investment amount (TL) are taken as inputs. As outputs, the number of customers, gross electricity generation (MWh), net consumption energy (MWh), the urban area served (km²) is used to measure of service efficiency of Turkish electric distribution companies. As we have seen through our literature review of nearly 100 studies, the use of these variables as inputs and outputs in measuring the efficiency of electricity distribution companies is widespread. Table 4.1. and Chart 4.1. show the results reached by counting the variables used in previous studies.

Table 4.1. Showing how often the variables are used as input and output in the literature review.

No	Variables	Inputs	Outputs
1	Gross Electricity Generation (MWh)	0	53
2	Net Consumption Energy (MWh)	5	40
3	Energy Loss (MWh)	29	4
4	Number of Villiges & Towns (NO)	0	0
5	Urban area served (km ²)	10	17
6	Number of Employees (Labour) (NO)	92	0
7	Number of Customers (NO)	4	88
8	Pupulation Number (NO)	0	1
9	Number of Transformers (NO)	4	2
10	Transformer Installed Power (MVA)	61	4
11	Length of the Grid in (aerial, cable lines) (km)	60	21
12	Number of poles (NO)	0	0
13	Number of Streets lighting (NO)	0	1
14	Number of Incidents (NO)	6	5
15	Investment Amount (TL)	35	0

**Chart 4.1.** Input and output variables.

We have data for 21 electricity distribution companies—these companies representing DMUs for each of the thirteen years in the DEA models. At the same time, nine of the fifteen variables related to companies were used as input and output variables in DEA models. The rest of the variables were used to build a new linear regression model to predict the annual technical efficiency of companies based on the regression variables only. These variables were distributed as five input variables, four output variables for DEA, and six variables for the regression equation. Table 4.2. shows the input, output, and regression variables, respectively.

Table 4.2. Input and output variables for DEA and regression variables.

DEA INPUTS					
Number of Employees (Labour) (NO)	Transformer Installed Power (MVA)	Length of the Grid in (aerial, cable lines) (km)	Energy Loss (MWh)	Investment Amount (TL)	
DEA OUTPUTS					
	Number of Customers (NO)	Gross Electricity Generation (MWh)	Net Consumption Energy (MWh)	Urban area served (km ²)	
THE VARIABLES OF REGRESSION					
Number of Villages & Towns (NO)	Population Number (NO)	Number of poles (NO)	Number of Streets lighting (NO)	Number of Incidents (NO)	Number of Transformers (NO)

4.2. Data Envelopment Analysis Models

We have used four models from the data envelopment analysis method, which are:

- A. Charnes-Cooper-Rhodes model (CCR) OR (Constant Returns to Scale) (CRS).
 1. Input-oriented Charnes-Cooper-Rhodes model (CCR-I).
 2. Output-oriented Charnes-Cooper-Rhodes model (CCR-O).
- B. Banker-Charnes-Cooper model (BCC) OR (Variable Returns to Scale) (VRS).
 1. Input-oriented Banker-Charnes-Cooper model (BCC-I).
 2. Output-oriented Banker-Charnes-Cooper model (BCC-O).

Input variables: the number of staff, installed power (MVA), length of cables (km), energy loss (MWh), and the investment amount (TL).

Output variables: the number of customers, gross electricity generation (MWh), net consumption energy (MWh), the urban area served (km²).

4.3. Results of Data Envelopment Analysis

The four models mentioned above were applied to our data on the 21 Turkish electricity distribution companies from 2007 to 2019 using the ready-made software (DEA-Solver-LV (V8)). As a result, we obtained annual efficiency results for each of the four models (CCR-I, CCR-O, BCC-I, BCC-O) for 13 years.

The annual efficiencies tables listed below show the companies' efficiency ranking for each model (CCR-I, CCR-O, BCC-I, BCC-O).

Table 4.3. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2007.

2007		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	1	1	1	1	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	0.8329	21	0.8329	21	0.8714	21	0.834	21
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	0.8539	19	0.8539	19	1	1	1	1
8	MERAM	0.8923	18	0.8923	18	1	1	1	1
9	BAŞKENT	0.8493	20	0.8493	20	1	1	1	1
10	AKDENİZ	0.9121	17	0.9121	17	0.9145	20	0.9127	20
11	GEDİZ	1	1	1	1	1	1	1	1
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZİÇİ	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	1	1	1	1	1	1	1	1
19	AYDEM	1	1	1	1	1	1	1	1
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	0.9818	16	0.9818	16	1	1	1	1

Table 4.4. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2008.

2008		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	1	1	1	1	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	0.8434	19	0.8434	19	0.9155	20	0.8607	21
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	0.7416	21	0.7416	21	1	1	1	1
8	MERAM	0.9304	17	0.9304	17	1	1	1	1
9	BAŞKENT	0.7884	20	0.7884	20	1	1	1	1
10	AKDENİZ	0.8924	18	0.8924	18	0.8962	21	0.8999	20
11	GEDİZ	1	1	1	1	1	1	1	1
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZİÇİ	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	1	1	1	1	1	1	1	1
19	AYDEM	1	1	1	1	1	1	1	1
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	0.9675	16	0.9675	16	1	1	1	1

Table 4.5. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2009.

2009		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	1	1	1	1	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	0.8721	19	0.8721	19	0.8743	21	0.8732	21
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	0.7496	21	0.7496	21	1	1	1	1
8	MERAM	1	1	1	1	1	1	1	1
9	BAŞKENT	0.9926	16	0.9926	16	1	1	1	1
10	AKDENİZ	0.9382	18	0.9382	18	0.9419	20	0.9393	20
11	GEDİZ	0.983	17	0.983	17	1	1	1	1
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZİÇİ	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	0.8479	20	0.8479	20	1	1	1	1
19	AYDEM	1	1	1	1	1	1	1	1
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	1	1	1	1	1	1	1	1

Table 4.6. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2010.

2010		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	1	1	1	1	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	0.7477	21	0.7477	21	0.7618	21	0.7524	21
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	0.8446	19	0.8446	19	1	1	1	1
8	MERAM	1	1	1	1	1	1	1	1
9	BAŞKENT	0.9819	16	0.9819	16	1	1	1	1
10	AKDENİZ	0.7785	20	0.7785	20	0.7788	20	0.814	20
11	GEDİZ	1	1	1	1	1	1	1	1
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZİÇİ	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	0.9353	18	0.9353	18	1	1	1	1
19	AYDEM	1	1	1	1	1	1	1	1
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	0.9638	17	0.9638	17	1	1	1	1

Table 4.7. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2011.

2011		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	1	1	1	1	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	0.9936	19	0.9936	19	1	1	1	1
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	0.7696	21	0.7696	21	1	1	1	1
8	MERAM	1	1	1	1	1	1	1	1
9	BAŞKENT	1	1	1	1	1	1	1	1
10	AKDENİZ	0.94	20	0.94	20	0.9513	21	0.9552	21
11	GEDİZ	1	1	1	1	1	1	1	1
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZİÇİ	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	1	1	1	1	1	1	1	1
19	AYDEM	1	1	1	1	1	1	1	1
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	1	1	1	1	1	1	1	1

Table 4.8. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2012.

2012		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	1	1	1	1	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	0.845	21	0.845	21	0.8684	21	0.8493	21
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	1	1	1	1	1	1	1	1
8	MERAM	1	1	1	1	1	1	1	1
9	BAŞKENT	1	1	1	1	1	1	1	1
10	AKDENİZ	0.9303	20	0.9303	20	0.9377	20	0.9489	20
11	GEDİZ	1	1	1	1	1	1	1	1
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZİÇİ	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	1	1	1	1	1	1	1	1
19	AYDEM	0.9342	19	0.9342	19	1	1	1	1
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	1	1	1	1	1	1	1	1

Table 4.9. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2013.

2013		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	0.9458	18	0.9458	18	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	0.8907	20	0.8907	20	0.9059	20	0.8993	20
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	1	1	1	1	1	1	1	1
8	MERAM	0.9388	19	0.9388	19	1	1	1	1
9	BAŞKENT	1	1	1	1	1	1	1	1
10	AKDENİZ	0.7021	21	0.7021	21	0.7921	21	0.8364	21
11	GEDİZ	1	1	1	1	1	1	1	1
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZİÇİ	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	1	1	1	1	1	1	1	1
19	AYDEM	0.9504	17	0.9504	17	0.9774	19	0.9745	19
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	1	1	1	1	1	1	1	1

Table 4.10. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2014.

2014		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	1	1	1	1	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	0.9784	19	0.9784	19	1	1	1	1
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	1	1	1	1	1	1	1	1
8	MERAM	0.9849	18	0.9849	18	1	1	1	1
9	BAŞKENT	1	1	1	1	1	1	1	1
10	AKDENİZ	1	1	1	1	1	1	1	1
11	GEDİZ	0.9396	20	0.9396	20	0.957	20	0.9638	20
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZİÇİ	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	1	1	1	1	1	1	1	1
19	AYDEM	0.8804	21	0.8804	21	0.8809	21	0.8888	21
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	1	1	1	1	1	1	1	1

Table 4.11. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2015.

2015		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	0.9987	19	0.9987	19	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	1	1	1	1	1	1	1	1
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	0.9798	21	0.9798	21	1	1	1	1
8	MERAM	0.9892	20	0.9892	20	1	1	1	1
9	BAŞKENT	1	1	1	1	1	1	1	1
10	AKDENİZ	1	1	1	1	1	1	1	1
11	GEDİZ	1	1	1	1	1	1	1	1
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZİÇİ	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	1	1	1	1	1	1	1	1
19	AYDEM	1	1	1	1	1	1	1	1
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	1	1	1	1	1	1	1	1

Table 4.12. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2016.

2016		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	0.9767	15	0.9767	15	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	0.9752	16	0.9752	16	1	1	1	1
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	0.9741	18	0.9741	18	1	1	1	1
8	MERAM	0.9745	17	0.9745	17	1	1	1	1
9	BAŞKENT	0.8231	21	0.8231	21	1	1	1	1
10	AKDENİZ	1	1	1	1	1	1	1	1
11	GEDİZ	0.9787	14	0.9787	14	1	1	1	1
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZİÇİ	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	0.9964	13	0.9964	13	1	1	1	1
19	AYDEM	0.9649	20	0.9649	20	0.9685	21	0.9694	21
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	0.9694	19	0.9694	19	1	1	1	1

Table 4.13. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2017.

2017		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	1	1	1	1	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	0.8651	17	0.8651	17	1	1	1	1
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	0.9075	16	0.9075	16	1	1	1	1
8	MERAM	0.9792	14	0.9792	14	1	1	1	1
9	BAŞKENT	0.7869	21	0.7869	21	1	1	1	1
10	AKDENİZ	1	1	1	1	1	1	1	1
11	GEDİZ	0.8081	19	0.8081	19	0.8203	21	0.844	20
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZİÇİ	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	0.801	20	0.801	20	1	1	1	1
19	AYDEM	0.8308	18	0.8308	18	0.8583	20	0.8409	21
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	0.9319	15	0.9319	15	1	1	1	1

Table 4.14. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2018.

2018		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	0.9489	16	0.9489	16	0.9966	18	0.9947	18
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	0.7538	18	0.7538	18	0.8868	21	0.7559	21
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	0.7313	19	0.7313	19	0.9714	19	0.9844	19
8	MERAM	0.9667	14	0.9667	14	1	1	1	1
9	BAŞKENT	0.7182	20	0.7182	20	1	1	1	1
10	AKDENİZ	1	1	1	1	1	1	1	1
11	GEDİZ	1	1	1	1	1	1	1	1
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZIÇI	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	0.7102	21	0.7102	21	1	1	1	1
19	AYDEM	0.9626	15	0.9626	15	0.9711	20	0.9736	20
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	0.9174	17	0.9174	17	1	1	1	1

Table 4.15. Showing the efficiency of distribution companies by using (CCR-I, CCR-O, BCC-I, BCC-O) models for 2019.

2019		Model = CCR-I		Model = CCR-O		Model = BCC-I		Model = BCC-O	
No.	DMU	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	DİCLE	1	1	1	1	1	1	1	1
2	VANGÖLÜ	1	1	1	1	1	1	1	1
3	ARAS	1	1	1	1	1	1	1	1
4	ÇORUH	1	1	1	1	1	1	1	1
5	FIRAT	1	1	1	1	1	1	1	1
6	ÇAMLIBEL	1	1	1	1	1	1	1	1
7	TOROSLAR	0.7263	21	0.7263	21	0.9811	19	0.9902	19
8	MERAM	0.949	16	0.949	16	1	1	1	1
9	BAŞKENT	0.8115	19	0.8115	19	1	1	1	1
10	AKDENİZ	0.9846	15	0.9846	15	1	1	1	1
11	GEDİZ	0.811	20	0.811	20	0.8113	21	0.876	20
12	ULUDAĞ	1	1	1	1	1	1	1	1
13	TRAKYA	1	1	1	1	1	1	1	1
14	AYEDAŞ	1	1	1	1	1	1	1	1
15	SAKARYA	1	1	1	1	1	1	1	1
16	OSMANGAZİ	1	1	1	1	1	1	1	1
17	BOĞAZIÇI	1	1	1	1	1	1	1	1
18	KAYSERİ VE CİVARI	0.8157	18	0.8157	18	1	1	1	1
19	AYDEM	0.8393	17	0.8393	17	0.8411	20	0.8544	21
20	AKEDAŞ	1	1	1	1	1	1	1	1
21	YEŞİLIRMAK	1	1	1	1	1	1	1	1

4.4. Conclusions of The First Stage: Applying Some Models

The results obtained from the application of the four models were classified as in Table 4.16 so that each company received four tests. In other words, four efficiency values annually over thirteen years. Thus, the total values of competencies for each firm are fifty-two. Each company's efficiency ratio was calculated to evaluate these companies and diagnose high-efficiency companies and low-efficiency companies.

From an overview of these results, we can conclude the following:

1. Each of the following 11 companies (**DICLE, ARAS, ÇORUH, ÇAMLIBEL, ULUDAĞ, TRAKYA, AAYDAŞ, SAKARYA, OSMANGAZİ, BOĞAZİÇİ, AKEDAŞ**) showed 100% efficiency in all models of (CCR-I, CCR-O, BCC-I, BCC-O) over the thirteen-year data period, did not obtain an efficiency of less than 1 in any of the years.
2. **VANGÖLÜ** Company achieved a total percentage efficiency of 81%, as its efficiency in (CCR-I, CCR-O) models was 69%, while its efficiency in (BCC-I, BCC-O) models was 92%.
3. **YEŞİLIRMAK** and **KAYSERİ VE CİVARI** achieved a total statistical efficiency of 77%, where their efficiency in (CCR-I, CCR-O) models was 54%. In contrast, their efficiency in (BCC-I, BCC-O) models was 100%.
4. Both **BAŞKENT** and **GEDİZ** achieved a total statistical efficiency of 69%. The efficiency of **BAŞKENT** company in (CCR-I, CCR-O) models was 39%. In contrast, its efficiency in (BCC-I, BCC-O) models was 100%. The efficiency of **GEDİZ** company in (CCR-I, CCR-O) models was 62%, while its efficiency in (BCC-I, BCC-O) models was 77%.
5. **MERAM** company achieved a statistical efficiency of 65%, as its efficiency in (CCR-I, CCR-O) models was 31%, while its efficiency in (BCC-I, BCC-O) models was 100%.
6. **TOROSLAR** Company achieved a relative efficiency of 54%, as its efficiency in (CCR-I, CCR-O) models was 23%, while its efficiency in (BCC-I, BCC-O) models was 85%.
7. **AYDEM** achieved a relative efficiency of 50%, as its efficiency in (CCR-I, CCR-O) models was 46%, while its efficiency in (BCC-I, BCC-O) models was 54%.
8. **Akdeniz** company achieved a specific efficiency of 42%, as its efficiency in (CCR-I, CCR-O) models was 39%, while its efficiency in (BCC-I, BCC-O) models was 46%.

9. Whereas **FIRAT** ranked last in terms of efficiency, with an efficiency of 31%, its efficiency in (CCR-I, CCR-O) models was 15%, while its efficiency in (BCC-I, BCC-O) models was 46%.

10. The best year for all electricity distribution companies in terms of relative efficiency was 2015. In this year, 18 companies achieved complete relative efficiency in (CCR-I, CCR-O) models, which is the most significant number obtained for efficient companies in all years in this model. Furthermore, just in this year, all companies have achieved complete relative efficiency at the same time in (BCC-I, BCC-O) models it was happened for once over 13 years.

11. The worst results were obtained in the comparative competency test for companies in 2018, where only 13 companies got full proficiency in (CCR-I, CCR-O) models. In contrast, 17 companies obtained full efficiency in the (BCC-I, BCC-O) models, which is the lowest number obtained for the efficient companies over 13 years in this model.

12. 2016 was the year with the lowest number of efficient companies in (CCR-I, CCR-O) models, where only 12 companies achieved full efficiency.

13. The percentage of the relative efficiency of all electricity distribution companies in the four test models (CCR-I, CCR-O, BCC-I, BCC-O) over 13 years was 81.7%, were 73% in the tests of (CCR-I, CCR-O) models, and 90.5% in tests of (BCC-I, BCC-O) models.

14. The overall efficiency achieved by the companies for 13 years through the application of the (CCR-I) and (CCR-O) models was 72.85%. While the total efficiency of the application of the (BCC-I) AND (BCC-O) models was 90.23%.

We note that all companies that have achieved efficiency through the two models (CCR-I, CCR-O) are also efficient in the two models (BCC-I, BCC-O), meaning that if the unit is efficient in the (CCR) model, it is efficient in the (BCC) model. Thus, the property of constant return is realized to the point of efficiency, and the opposite is not always true.

To standardize the results for the relative efficiency of the electricity distribution companies that we obtained, we created Table 4.16. and Chart 4.2. to show the number of iterations of relative efficiency achieved by each company and their percentage. Each company passed 52 tests over a 13-year period.

To see the results we obtained from another angle, i.e., based on years, we created Table 4.17. and Chart 4.3. to show the number of successes achieved by companies combined in each year to obtain the complete relative efficiency and its percentage, given that

each company passed four tests (CCR-I, CCR-O, BCC-I, BCC-O) per year. Thus, we have 84 test results in one year.

Table 4.16. Shows the number of times that each company achieved complete relative efficiency by applying the models (CCR-I, CCR-O, BCC-I, BCC-O) for 13 years.

2007 -2019		CCR-I		CCR-O		BCC-I		BCC-O		Total	
No.	DMU	Score	Efficiency %	Score	Efficiency %	Score	Efficiency %	Score	Efficiency %	Sum	Efficiency %
1	DICLE	13	100%	13	100%	13	100%	13	100%	52	100%
2	VANGÖLÜ	9	69%	9	69%	12	92%	12	92%	42	81%
3	ARAS	13	100%	13	100%	13	100%	13	100%	52	100%
4	ÇORUH	13	100%	13	100%	13	100%	13	100%	52	100%
5	FIRAT	2	15%	2	15%	6	46%	6	46%	16	31%
6	ÇAMLIBEL	13	100%	13	100%	13	100%	13	100%	52	100%
7	TOROSLAR	3	23%	3	23%	11	85%	11	85%	28	54%
8	MERAM	4	31%	4	31%	13	100%	13	100%	34	65%
9	BAŞKENT	5	39%	5	39%	13	100%	13	100%	36	69%
10	AKDENİZ	5	39%	5	39%	6	46%	6	46%	22	42%
11	GEDİZ	8	62%	8	62%	10	77%	10	77%	36	69%
12	ULUDAĞ	13	100%	13	100%	13	100%	13	100%	52	100%
13	TRAKYA	13	100%	13	100%	13	100%	13	100%	52	100%
14	AYEDAŞ	13	100%	13	100%	13	100%	13	100%	52	100%
15	SAKARYA	13	100%	13	100%	13	100%	13	100%	52	100%
16	OSMANGAZİ	13	100%	13	100%	13	100%	13	100%	52	100%
17	BOĞAZİÇİ	13	100%	13	100%	13	100%	13	100%	52	100%
18	KAYSERİ VE CİVARI	7	54%	7	54%	13	100%	13	100%	40	77%
19	AYDEM	6	46%	6	46%	7	54%	7	54%	26	50%
20	AKEDAŞ	13	100%	13	100%	13	100%	13	100%	52	100%
21	YEŞİLIRMAK	7	54%	7	54%	13	100%	13	100%	40	77%
Total		199	73%	199	73%	247	90.50%	247	90.50%	892	82%

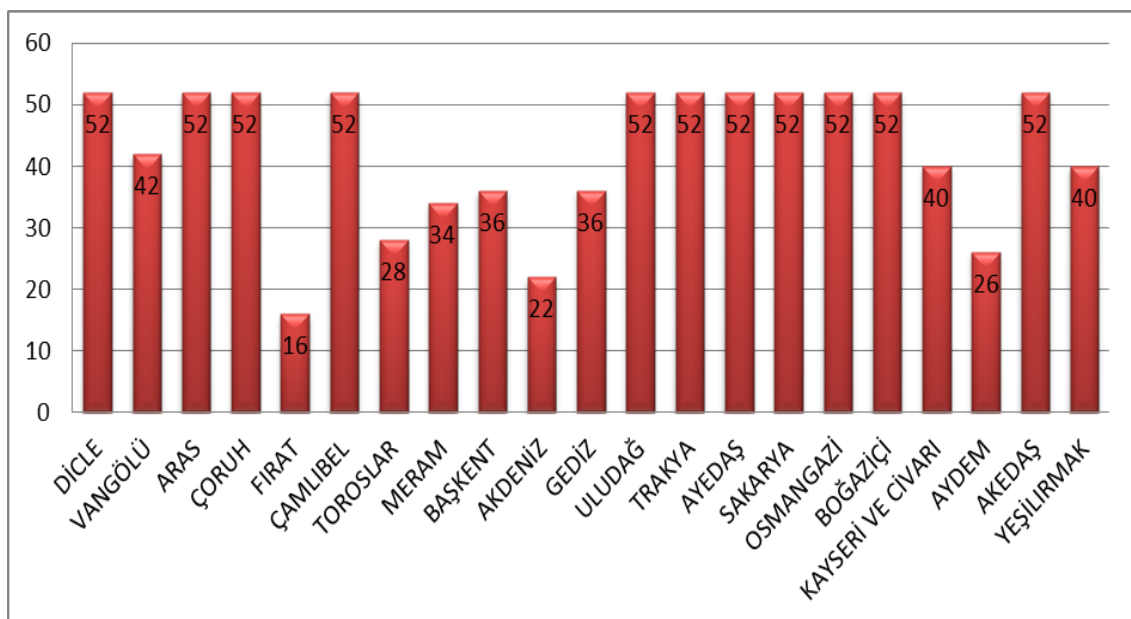


Chart 4.2. The frequency of the efficiency of companies over 13 years.

Table 4.17. Shows the number of companies that achieved the complete relative efficiency every year by applying the models (CCR-I, CCR-O, BCC-I, BCC-O) for 13 years.

2007-2019	CCR-I		CCR-O		BCC-I		BCC-O		Total	
Years	No. Of Efficiency companies	Efficiency %	No. Of Efficiency companies	Efficiency %	No. Of Efficiency companies	Efficiency %	No. Of Efficiency companies	Efficiency %	The Sum	Total Efficiency %
2007	15	71%	15	71%	19	90%	19	90%	68	81%
2008	15	71%	15	71%	19	90%	19	90%	68	81%
2009	15	71%	15	71%	19	90%	19	90%	68	81%
2010	15	71%	15	71%	19	90%	19	90%	68	81%
2011	18	86%	18	86%	20	95%	20	95%	76	90%
2012	18	86%	18	86%	19	90%	19	90%	74	88%
2013	16	76%	16	76%	18	86%	18	86%	68	81%
2014	17	81%	17	81%	19	90%	19	90%	72	86%
2015	18	86%	18	86%	21	100%	21	100%	78	93%
2016	12	57%	12	57%	20	95%	20	95%	64	76%
2017	13	62%	13	62%	19	90%	19	90%	64	76%
2018	13	62%	13	62%	17	81%	17	81%	60	71%
2019	14	67%	14	67%	18	86%	18	86%	64	76%
Total	199	73%	199	73%	247	90.23%	247	90.23%	892	82%

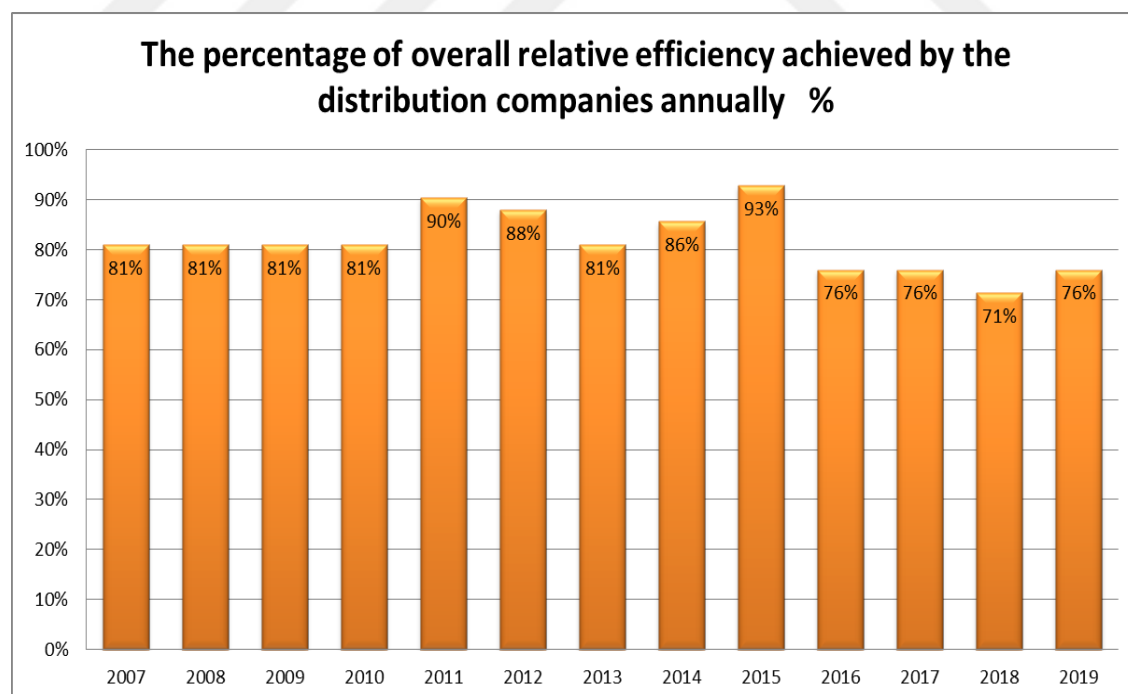


Chart 4.3. The percentage of overall relative efficiency achieved by the distribution companies annually over 13 years.

5. THE SECOND STAGE: APPLICATION OF QUANTILE REGRESSION ANALYSIS

5.1. Operations To Be Performed In A Regression Analysis

5.1.1. Regression analysis

In the second stage, we used the results obtained in the first stage with some modifications. When we used the models (CCR-I, CCR-O, BCC-I, BCC-O) in the first stage for 13 years, we had 52 efficiency tables. Because the efficiency values of CCR-I and CCR-O were the same, we combined them and considered them as one value and collected them in one model in the regression analysis equations; we called it the CCR-I/O model. As a result, we will have 39 regression models in the second stage instead of 52, with three models per year (CCR-I/O, BCC-I, BCC-O) and not four models. In the second stage, we used the efficiency degrees of companies as a dependent variable in the regression models, after which to find out the effect of external variables on performance, the following regression models were used:

1. Beta regression analysis.
2. Kumaraswamy regression analysis.
3. UGHN regression analysis.

Beta regression is classic regression analysis, but Kumaraswamy and UGHN are a quantile type regression analysis.

Regression variables:

- **External variables:** Number of villages and towns, Number of poles, Distribution company region population, Annual breakdown and interruption, Number of transformers, Number of fixtures and lamps.
- **Dependent variable:** The efficiency score were examined.

5.1.2 Maximum likelihood estimation

We used the maximum likelihood estimation (MLE) method for estimating the parameters of regression models. So we used the log-likelihood function.

5.1.3 Model validity

After models fitting, the problem is whether the regression models are suitable or not. In this context, residual analysis plays an essential role in models validity. In order to see this, it will be focused on the randomized quantile residuals see{Dunn, 1996 #65}. If the fitted model successfully deals with the data set, the distribution of the randomized quantile residuals will correspond to the standard normal distribution with zero mean and one variance. To access that, we used three tests for goodness of fit:

1. One-sample Kolmogorov-Smirnov test.
2. One-sample Anderson-Darling test of goodness-of-fit.
3. One-sample Cramer-von Mises test of goodness-of-fit.

5.1.4. R program

We were used the R program to calculate the regression analysis of (Beta, Kumaraswamy, (UGHN)), and the maxLik function [maxlike] with the Nelder-Mead optimization method to maximize directly. The maxLik function in the R program also derives asymptotic standard errors of the estimations numerically. At last, we also used the R program to test the goodness-of-fit of regression models. We used the Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

5.2. Results Of Regression Analysis

What came in the second stage has been applied to all the data from 2007 to 2019. All of the results that we obtained at this stage through the use of the R program. The results we got from the regression analysis are as follows:

CCRI/O 2007

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
-1.6257	-0.5620	-0.1054	0.5499	2.6895

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.1797	0.6402	6.529	6.62e-11 ***
x1	1.1783	1.3743	0.857	0.3913
x2	2.8614	1.5729	1.819	0.0689 .
x3	1.4710	1.6286	0.903	0.3664
x4	-1.9561	3.7572	-0.521	0.6026
x5	-0.7580	2.5184	-0.301	0.7634
x6	-4.3981	5.1683	-0.851	0.3948

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	10.466	4.836	2.164	0.0305 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **97.33** on 8 Df

Pseudo R-squared: 0.5181

Number of iterations: 167 (BFGS) + 12 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 2045 iterations

Return code 0: successful convergence

Log-Likelihood: **100.9787**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	12.35930	0.07715	160.19	<2e-16 ***
gama1	-4.27151	0.21406	-19.95	<2e-16 ***
gama2	13.99737	0.19287	72.57	<2e-16 ***
gama3	15.49937	0.03927	394.64	<2e-16 ***
gama4	-12.78816	0.28460	-44.93	<2e-16 ***
gama5	2.80133	0.06206	45.14	<2e-16 ***
gama6	-24.33244	0.25022	-97.24	<2e-16 ***
alpha	31.04902	0.40312	77.02	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of (UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1921 iterations
Return code 0: successful convergence
Log-Likelihood: **106.3946**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	9.77102	1.41310	6.915	4.69e-12 ***
gama1	-0.70644	0.16014	-4.411	1.03e-05 ***
gama2	6.54232	2.36481	2.767	0.00567 **
gama3	3.88800	1.19661	3.249	0.00116 **
gama4	-7.77223	0.94940	-8.186	2.69e-16 ***
gama5	-2.23710	0.20522	-10.901	< 2e-16 ***
gama6	-6.52619	0.81077	-8.049	8.32e-16 ***
alpha	0.40512	0.07385	5.486	4.11e-08 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.1. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2007.

2007 CCRI/O	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.20563	0.2948	0.85986	0.4384	0.17791	0.3163
Kumar Reg. Residuals	0.14351	0.7278	0.66023	0.591	0.083592	0.6763
UGHN Reg. Residuals	0.10744	0.9473	0.24278	0.974	0.033875	0.965

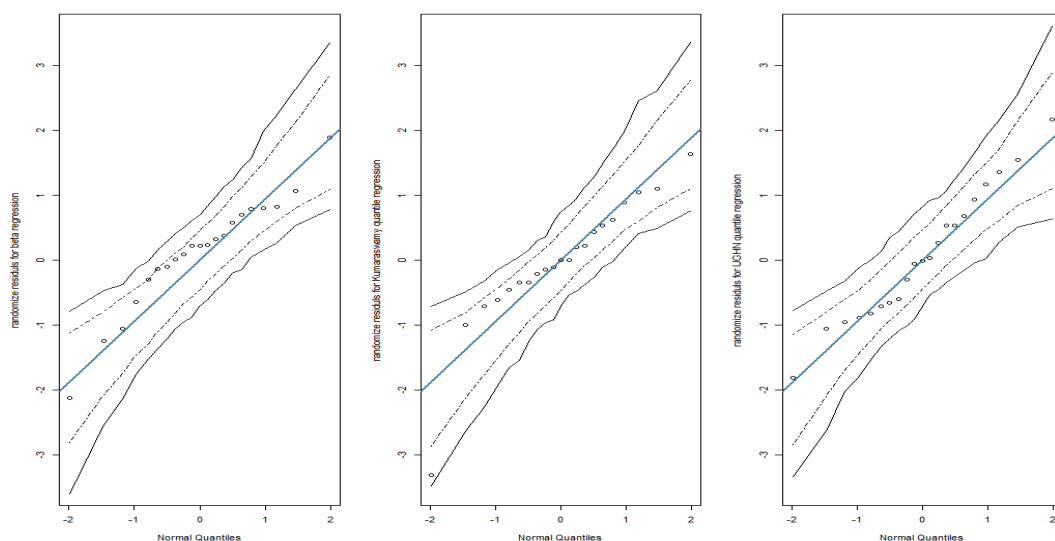


Figure 5.1. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2007.

BCCI 2007

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
-1.5624	-0.4190	0.0228	0.5306	0.9279

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.041	0.632	6.394	1.62e-10 ***
x1	1.806	1.414	1.278	0.201
x2	1.256	1.657	0.758	0.448
x3	2.446	1.648	1.484	0.138
x4	3.797	3.774	1.006	0.314
x5	2.908	2.558	1.137	0.256
x6	-8.541	5.230	-1.633	0.102

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	20.48	10.66	1.921	0.0547 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **120.8** on 8 Df

Pseudo R-squared: 0.3925

Number of iterations: 2720 (BFGS) + 11 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 2157 iterations

Return code 0: successful convergence

Log-Likelihood: **121.2772**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	6.0768	0.7321	8.300	< 2e-16 ***
gama1	3.9580	1.0210	3.877	0.000106 ***
gama2	9.2229	0.3348	27.549	< 2e-16 ***
gama3	18.8281	1.4833	12.693	< 2e-16 ***
gama4	3.7704	0.7917	4.762	1.91e-06 ***
gama5	9.1448	0.4862	18.807	< 2e-16 ***
gama6	-34.5038	0.8208	-42.039	< 2e-16 ***
alpha	28.0690	10.0031	2.806	0.005016 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 985 iterations
Return code 0: successful convergence
Log-Likelihood: **128.47**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	6.60326	0.62067	10.639	< 2e-16 ***
gama1	-2.02228	0.61941	-3.265	0.001095 **
gama2	6.03000	0.61184	9.856	< 2e-16 ***
gama3	-3.48917	0.71597	-4.873	1.10e-06 ***
gama4	3.12269	0.53327	5.856	4.75e-09 ***
gama5	-1.97874	0.62183	-3.182	0.001462 **
gama6	5.27045	1.77625	2.967	0.003005 **
alpha	0.30797	0.08941	3.445	0.000572 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.2. The results of testing the goodness of fit for the residual of the regression models for BCCI 2007.

2007 BCCI	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.32389	0.01843	2.8053	0.0349	0.59645	0.02188
Kumar Reg. Residuals	0.30697	0.02968	2.3163	0.06256	0.42665	0.06056
UGHN Reg. Residuals	0.23799	0.157	1.4202	0.1968	0.24253	0.1986

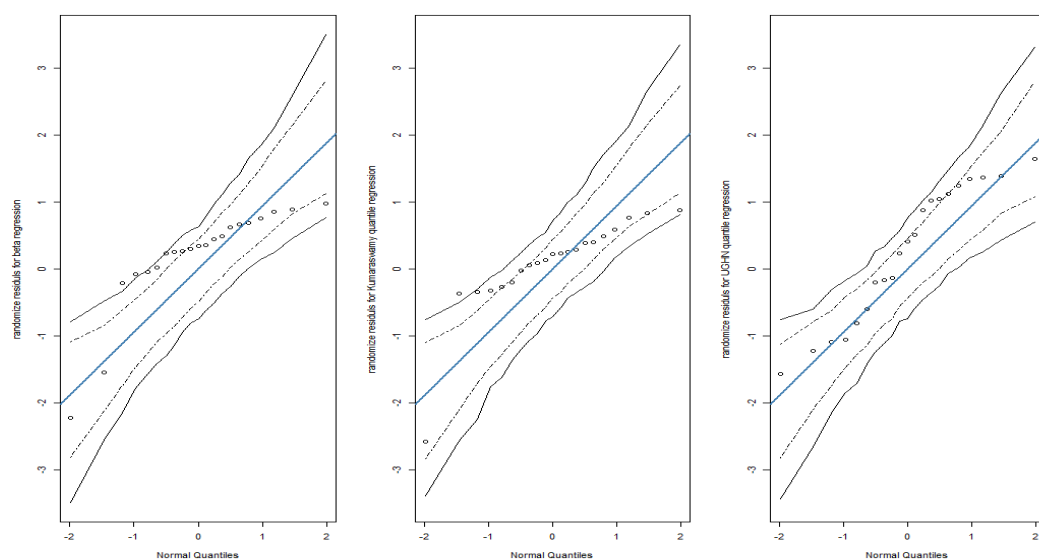


Figure 5.2. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2007.

BCCO 2007

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
-1.5788	-0.4085	0.0265	0.5259	0.8733

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	3.8776	0.6411	6.049	1.46e-09 ***
x1	1.7480	1.4195	1.231	0.218
x2	1.1932	1.6640	0.717	0.473
x3	2.3415	1.6550	1.415	0.157
x4	3.7440	3.7878	0.988	0.323
x5	2.8306	2.5667	1.103	0.270
x6	-8.2830	5.2488	-1.578	0.115

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	16.412	8.621	1.904	0.0569 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **119.9** on 8 Df

Pseudo R-squared: 0.3897

Number of iterations: 3497 (BFGS) + 13 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 4021 iterations

Return code 0: successful convergence

Log-Likelihood: **125.9173**

Eight free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	3.096e+00	1.141e-01	27.12	<2e-16 ***
gama1	3.246e+01	1.401e-02	2317.57	<2e-16 ***
gama2	8.467e+00	9.915e-03	853.92	<2e-16 ***
gama3	2.776e+01	2.074e-01	133.88	<2e-16 ***
gama4	7.261e+01	1.513e-01	479.92	<2e-16 ***
gama5	3.856e+01	7.949e-03	4850.54	<2e-16 ***
gama6	-1.266e+02	1.941e-03	-65233.81	<2e-16 ***
alpha	6.306e+01	1.736e-02	3631.48	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1873 iterations
Return code 0: successful convergence
Log-Likelihood: **138.4124**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.40761	0.24553	34.243	< 2e-16 ***
gama1	-2.84622	0.36334	-7.834	4.74e-15 ***
gama2	0.84162	0.16465	5.112	3.19e-07 ***
gama3	7.39456	0.22996	32.156	< 2e-16 ***
gama4	-7.87730	0.33903	-23.235	< 2e-16 ***
gama5	-1.30315	0.39570	-3.293	0.00099 ***
gama6	2.45596	0.04561	53.845	< 2e-16 ***
alpha	0.69850	0.12896	5.416	6.08e-08 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.3. The results of testing the goodness of fit for the residual of the regression models for BCCO 2007.

2007 BCCO	One-sample Kolmogorov-Smir nov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.33302	0.01408	2.9229	0.03042	0.62078	0.01896
Kumar Reg. Residuals	0.20446	0.301	1.5619	0.1626	0.24532	0.1948
UGHN Reg. Residuals	0.24091	0.1476	1.5577	0.1635	0.24808	0.1911

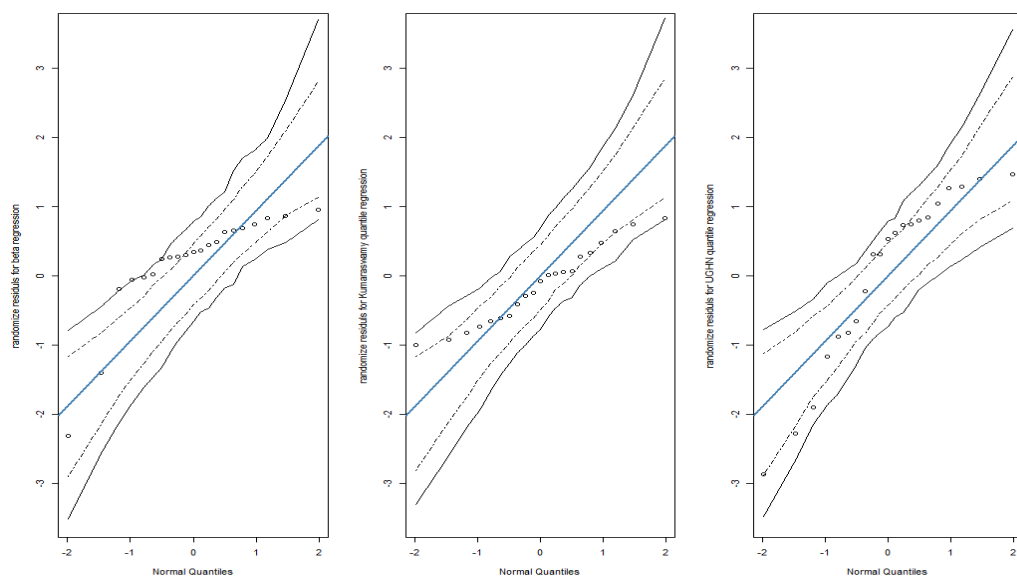


Figure 5.3. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2007.

CCRI/O 2008

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
-1.6795	-0.3847	-0.1324	0.6572	2.3232

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.3997	0.6871	6.403	1.52e-10 ***
x1	0.4488	1.1964	0.375	0.708
x2	1.1560	1.4426	0.801	0.423
x3	0.1469	1.2977	0.113	0.910
x4	-3.2164	2.7986	-1.149	0.250
x5	-1.3924	2.0298	-0.686	0.493
x6	-0.6921	3.5093	-0.197	0.844

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	7.738	3.581	2.161	0.0307 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **94.91** on 8 Df

Pseudo R-squared: 0.4164

Number of iterations: 110 (BFGS) + 7 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 749 iterations

Return code 0: successful convergence

Log-Likelihood: **98.70832**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	14.32236	0.08304	172.484	< 2e-16 ***
gama1	-5.15041	0.07170	-71.837	< 2e-16 ***
gama2	5.95479	0.16219	36.714	< 2e-16 ***
gama3	0.42533	0.11706	3.633	0.000280 ***
gama4	-6.43082	0.11389	-56.467	< 2e-16 ***
gama5	3.23777	0.07870	41.139	< 2e-16 ***
gama6	-10.40388	0.08836	-117.741	< 2e-16 ***
alpha	31.49015	8.43078	3.735	0.000188 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 2565 iterations

Return code 0: successful convergence

Log-Likelihood: **101.3853**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	6.00256	0.06904	86.944	< 2e-16 ***
gama1	10.93989	0.33230	32.922	< 2e-16 ***
gama2	10.64117	0.17742	59.977	< 2e-16 ***
gama3	2.52630	0.22087	11.438	< 2e-16 ***
gama4	-10.04556	1.70371	-5.896	3.72e-09 ***
gama5	-8.78363	1.69476	-5.183	2.19e-07 ***
gama6	-8.53472	1.65384	-5.161	2.46e-07 ***
alpha	0.34795	0.05258	6.618	3.64e-11 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.4. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2008.

2008 CCRI/O	One-sample Kolmogorov-Smir Nov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.23364	0.1718	0.77359	0.4988	0.16366	0.3525
Kumar Reg. Residuals	0.16417	0.5677	1.1064	0.3053	0.13917	0.4271
UGHN Reg. Residuals	0.21761	0.2362	0.81932	0.4657	0.15929	0.3646

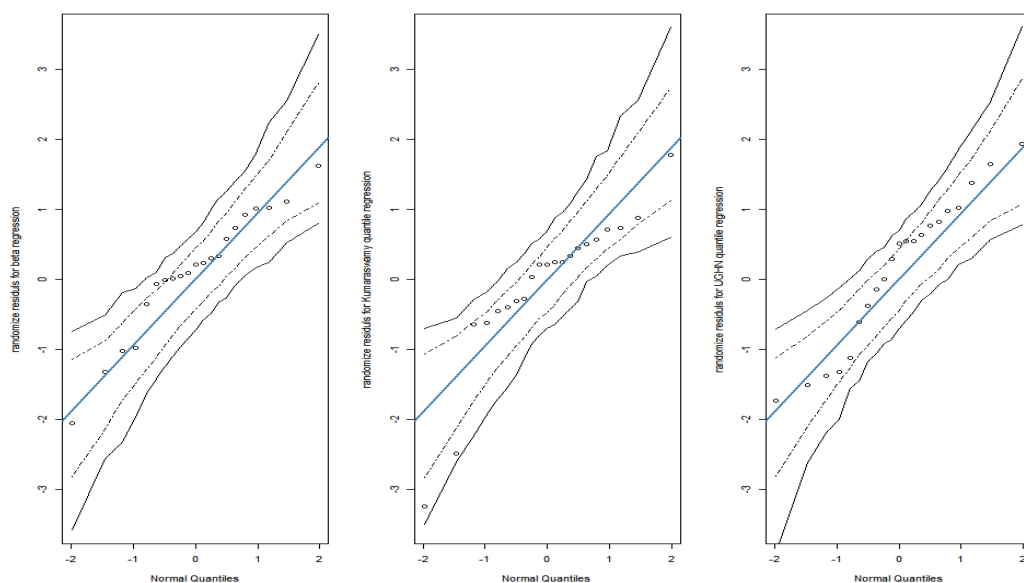


Figure 5.4. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2008.

BCCI 2008

```
summary(gy) ## The results of Beta regression analysis ##
betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")
Standardized weighted residuals 2:
```

	Min	1Q	Median	3Q	Max
	-1.4554	-0.1015	0.1193	0.2700	0.7342

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.3571	0.6697	6.506	7.72e-11 ***
x1	0.7055	1.2427	0.568	0.570
x2	0.9005	1.4958	0.602	0.547
x3	0.6603	1.2929	0.511	0.610
x4	0.7913	2.8535	0.277	0.782
x5	0.5949	2.0385	0.292	0.770
x6	-2.3422	3.6300	-0.645	0.519

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	21.41	11.38	1.881	0.06 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **120.9** on 8 Df

Pseudo R-squared: 0.1998

Number of iterations: 195 (BFGS) + 5 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 2705 iterations

Return code 0: successful convergence

Log-Likelihood: **121.1398**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	4.13120	0.75313	5.485	4.13e-08 ***
gama1	9.02229	0.04432	203.559	< 2e-16 ***
gama2	7.68296	1.71758	4.473	7.71e-06 ***
gama3	6.96187	1.23815	5.623	1.88e-08 ***
gama4	32.67013	1.88361	17.344	< 2e-16 ***
gama5	14.50471	1.23777	11.718	< 2e-16 ***
gama6	-45.07463	4.21944	-10.683	< 2e-16 ***
alpha	52.18626	2.43955	21.392	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1733 iterations
Return code 0: successful convergence
Log-Likelihood: **140.1903**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	7.0304	0.7966	8.826	< 2e-16 ***
gama1	2.4305	0.5110	4.756	1.97e-06 ***
gama2	6.0988	1.5215	4.009	6.11e-05 ***
gama3	1.0605	0.1836	5.777	7.60e-09 ***
gama4	5.9642	0.3579	16.664	< 2e-16 ***
gama5	2.9497	0.2925	10.083	< 2e-16 ***
gama6	-9.6983	0.2837	-34.181	< 2e-16 ***
alpha	0.6414	0.2134	3.005	0.00266 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.5. The results of testing the goodness of fit for the residual of the regression models for BCCI 2008.

2008 BCCI	One-sample Kolmogorov-Smir Nov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.44914	0.0002198	4.5133	0.005042	0.97591	0.002401
Kumar Reg. Residuals	0.23084	0.182	1.7466	0.1276	0.29817	0.1365
UGHN Reg. Residuals	0.18572	0.4133	1.0095	0.3513	0.1634	0.3532

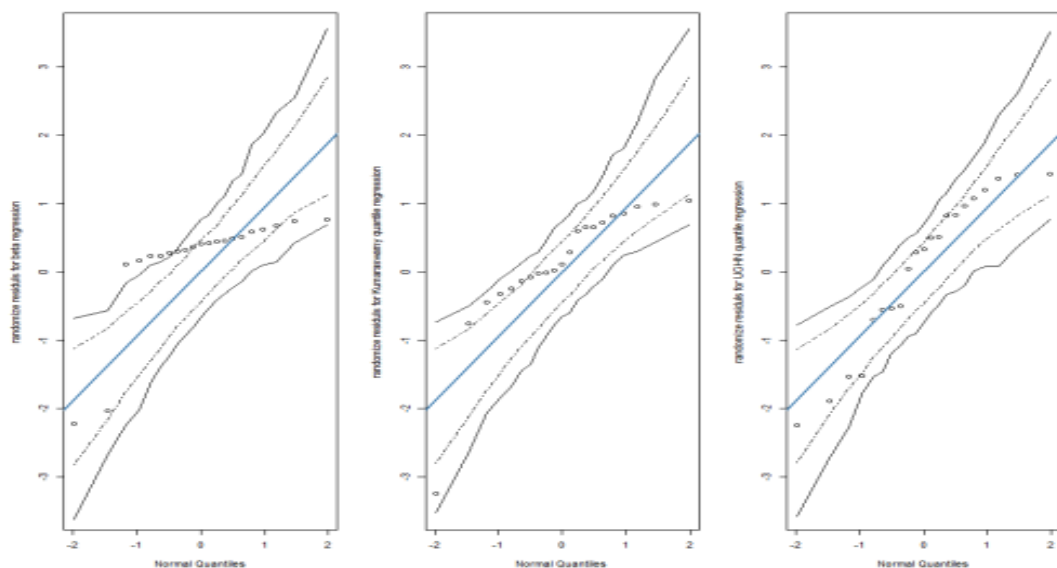


Figure 5.5. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2008.

BCCO 2008

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-1.3967	-0.1087	0.1421	0.2858	0.6918

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.1141	0.6785	6.063	1.33e-09 ***
x1	0.6909	1.2484	0.553	0.580
x2	0.8565	1.5030	0.570	0.569
x3	0.6375	1.2994	0.491	0.624
x4	0.9203	2.8660	0.321	0.748
x5	0.6509	2.0478	0.318	0.751
x6	-2.3959	3.6462	-0.657	0.511

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	15.942	8.568	1.861	0.0628 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **119.5** on 8 Df

Pseudo R-squared: 0.1971

Number of iterations: 138 (BFGS) + 6 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 4349 iterations

Return code 0: successful convergence

Log-Likelihood: **121.1523**

Eight free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	3.259e+00	1.885e-01	17.29	<2e-16 ***
gama1	1.151e+01	7.598e-03	1514.61	<2e-16 ***
gama2	1.142e+01	8.369e-05	136480.17	<2e-16 ***
gama3	8.762e+00	6.471e-01	13.54	<2e-16 ***
gama4	3.684e+01	5.352e-01	68.83	<2e-16 ***
gama5	1.410e+01	3.916e-04	36008.99	<2e-16 ***
gama6	-5.217e+01	7.598e-03	-6866.84	<2e-16 ***
alpha	4.180e+01	4.808e-02	869.29	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1765 iterations
Return code 0: successful convergence
Log-Likelihood: **142.3466**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.9607	0.4600	19.480	< 2e-16 ***
gama1	-1.7540	0.4019	-4.364	1.28e-05 ***
gama2	-3.4408	0.4420	-7.784	7.01e-15 ***
gama3	1.7714	0.5563	3.184	0.00145 **
gama4	4.0018	0.7139	5.605	2.08e-08 ***
gama5	5.0353	0.7155	7.037	1.96e-12 ***
gama6	-2.9820	0.3561	-8.374	< 2e-16 ***
alpha	0.7161	0.1306	5.482	4.21e-08 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.6. The results of testing the goodness of fit for the residual of the regression models for BCCO 2008.

2008 BCCO	One-sample Kolmogorov-Smir Nov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.44089	0.0003098	4.5296	0.004952	0.9829	0.002306
Kumar Reg. Residuals	0.19474	0.3564	1.3959	0.2034	0.22251	0.2284
UGHN Reg. Residuals	0.17854	0.4621	1.0046	0.3539	0.14567	0.4056

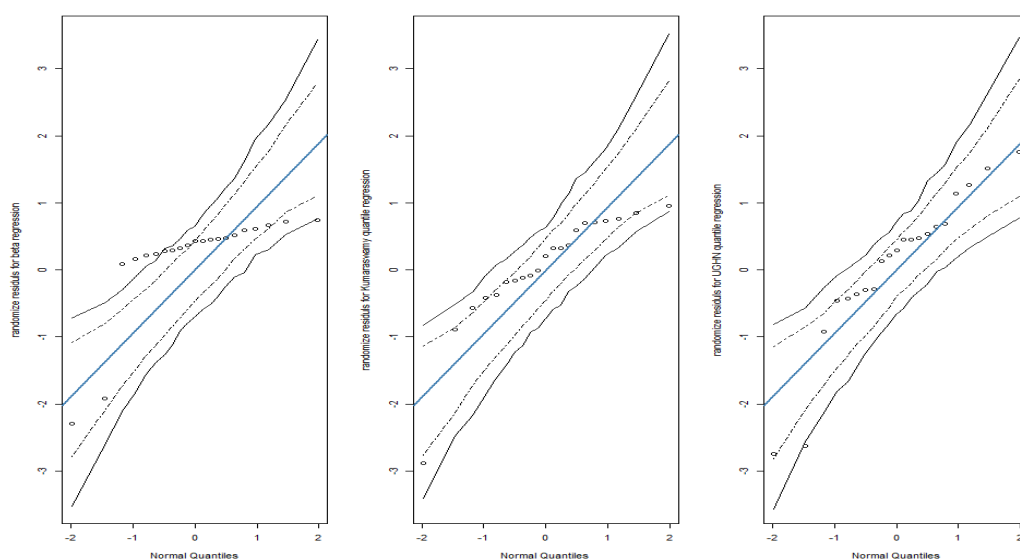


Figure 5.6. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2008.

CCRI/O 2009

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-1.9667	-0.2423	0.0306	0.3590	1.6048

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	3.6623	0.6745	5.429	5.66e-08 ***
x1	0.6592	1.2974	0.508	0.611
x2	0.9582	1.8903	0.507	0.612
x3	1.7918	1.6541	1.083	0.279
x4	-1.9557	2.9615	-0.660	0.509
x5	0.7982	2.0178	0.396	0.692
x6	-2.6597	3.2387	-0.821	0.412

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	8.106	3.932	2.062	0.0392 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **97.77** on 8 Df

Pseudo R-squared: 0.3068

Number of iterations: 137 (BFGS) + 18 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 979 iterations

Return code 0: successful convergence

Log-Likelihood: **99.80076**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	4.1843	0.1121	37.324	<2e-16 ***
gama1	6.1977	0.2217	27.956	<2e-16 ***
gama2	16.2353	0.4621	35.134	<2e-16 ***
gama3	16.2756	1.9622	8.295	<2e-16 ***
gama4	-42.8643	1.5093	-28.401	<2e-16 ***
gama5	-19.9719	0.1448	-137.936	<2e-16 ***
gama6	9.0761	0.1825	49.744	<2e-16 ***
alpha	20.7681	1.1798	17.604	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1229 iterations

Return code 0: successful convergence

Log-Likelihood: **108.766**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	5.56451	0.26965	20.636	< 2e-16 ***
gama1	6.88576	0.90276	7.627	2.39e-14 ***
gama2	4.31843	0.88258	4.893	9.93e-07 ***
gama3	7.90260	1.13222	6.980	2.96e-12 ***
gama4	5.10819	1.32159	3.865	0.000111 ***
gama5	9.38322	0.54331	17.270	< 2e-16 ***
gama6	-22.93486	0.29279	-78.333	< 2e-16 ***
alpha	0.39922	0.08434	4.734	2.21e-06 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.7. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2009.

2009 CCRI/O	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.34627	0.009396	2.0429	0.08759	0.44342	0.05465
Kumar Reg. Residuals	0.15174	0.6641	0.50635	0.7384	0.077304	0.7128
UGHN Reg. Residuals	0.13471	0.793	0.29723	0.9396	0.045742	0.9064

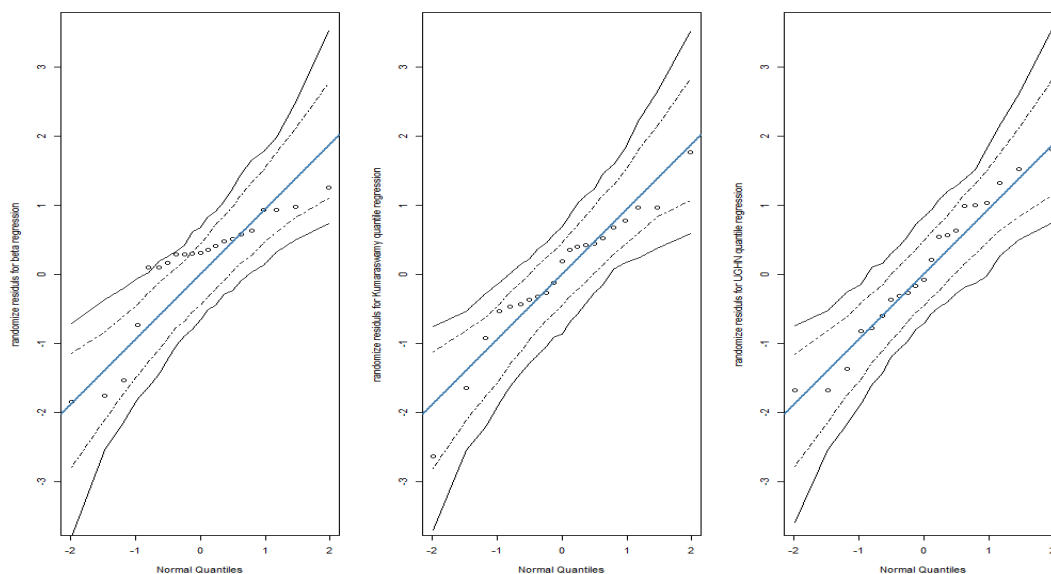


Figure 5.7. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2009.

BCCI 2009

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-1.6160	-0.3649	0.0571	0.5196	0.9601

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.2968	0.6481	6.629	3.37e-11 ***
x1	1.3865	1.2816	1.082	0.2793
x2	0.9885	1.8598	0.532	0.5951
x3	0.8222	1.6172	0.508	0.6111
x4	3.7921	2.9486	1.286	0.1984
x5	2.2894	1.9903	1.150	0.2500
x6	-5.7960	3.2260	-1.797	0.0724 .

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	24.74	12.77	1.938	0.0526 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **121.8** on 8 Df

Pseudo R-squared: 0.3925

Number of iterations: 4535 (BFGS) + 13 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1467 iterations

Return code 0: successful convergence

Log-Likelihood: **129.2727**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	7.969e+00	2.021e-02	394.3	<2e-16 ***
gama1	6.203e+00	2.534e-03	2447.9	<2e-16 ***
gama2	1.851e+01	2.004e-02	923.6	<2e-16 ***
gama3	1.978e+01	5.454e-03	3625.8	<2e-16 ***
gama4	4.160e+01	7.584e-04	54845.2	<2e-16 ***
gama5	2.228e+01	3.147e-02	708.0	<2e-16 ***
gama6	-7.169e+01	3.503e-02	-2046.4	<2e-16 ***
alpha	1.450e+02	5.553e-03	26105.7	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 2013 iterations
Return code 0: successful convergence
Log-Likelihood: **140.3018**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.50626	0.41107	20.693	< 2e-16 ***
gama1	-1.93236	0.41672	-4.637	3.53e-06 ***
gama2	0.77591	0.23966	3.238	0.00121 **
gama3	5.43281	0.74590	7.284	3.25e-13 ***
gama4	-8.00081	0.64582	-12.389	< 2e-16 ***
gama5	-2.88168	0.26995	-10.675	< 2e-16 ***
gama6	3.68915	0.06483	56.903	< 2e-16 ***
alpha	0.68040	0.16028	4.245	2.18e-05 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.8. The results of testing the goodness of fit for the residual of the regression models for BCCI 2009.

2009 BCCI	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.33006	0.01538	2.8639	0.03259	0.60908	0.02031
Kumar Reg. Residuals	0.20629	0.2914	1.6742	0.1402	0.29193	0.1422
UGHN Reg. Residuals	0.23282	0.1748	1.4036	0.2012	0.22294	0.2277

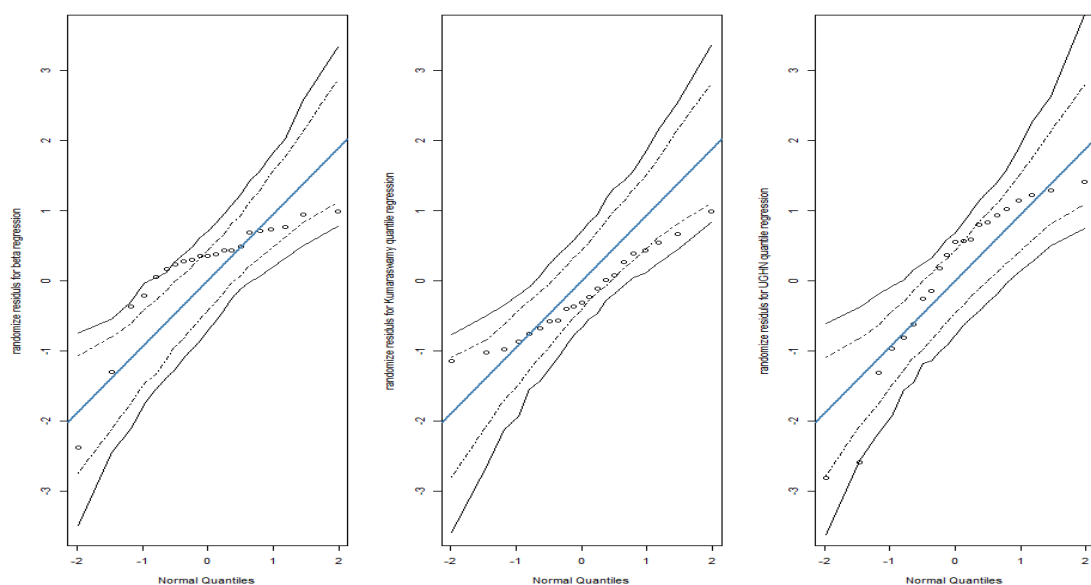


Figure 5.8. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2009.

BCCO 2009

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
-1.6092	-0.3667	0.0565	0.5215	0.9605

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.2755	0.6486	6.592	4.34e-11 ***
x1	1.3932	1.2821	1.087	0.2772
x2	0.9948	1.8604	0.535	0.5928
x3	0.8272	1.6177	0.511	0.6091
x4	3.7969	2.9495	1.287	0.1980
x5	2.2932	1.9909	1.152	0.2494
x6	-5.8146	3.2272	-1.802	0.0716 .

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	24.18	12.49	1.936	0.0528 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **121.7** on 8 Df

Pseudo R-squared: 0.393

Number of iterations: 3823 (BFGS) + 14 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 3031 iterations

Return code 0: successful convergence

Log-Likelihood: **131.1575**

Eight free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	5.619e+00	3.858e-04	14562.2	<2e-16 ***
gama1	1.036e+01	7.363e-03	1407.1	<2e-16 ***
gama2	3.256e+01	2.310e-02	1409.5	<2e-16 ***
gama3	8.776e+00	7.306e-03	1201.2	<2e-16 ***
gama4	2.860e+01	2.719e-01	105.2	<2e-16 ***
gama5	8.912e+00	2.420e-02	368.3	<2e-16 ***
gama6	-5.490e+01	2.356e-05	-2329805.7	<2e-16 ***
alpha	1.907e+02	2.845e-01	670.3	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1683 iterations
Return code 0: successful convergence
Log-Likelihood: **136.2072**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	10.80590	1.77871	6.075	1.24e-09 ***
gama1	-5.80688	1.30143	-4.462	8.12e-06 ***
gama2	-10.72060	2.35223	-4.558	5.17e-06 ***
gama3	-7.08156	1.36804	-5.176	2.26e-07 ***
gama4	4.40001	1.50620	2.921	0.003486 **
gama5	4.70798	1.23974	3.798	0.000146 ***
gama6	13.24147	2.95810	4.476	7.59e-06 ***
alpha	0.47872	0.09368	5.110	3.22e-07 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.9. The results of testing the goodness of fit for the residual of the regression models for BCCO

2009 BCCO	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.32978	0.0155	2.8542	0.03296	0.60759	0.02049
Kumar Reg. Residuals	0.21944	0.228	1.1919	0.2701	0.20727	0.2547
UGHN Reg. Residuals	0.19116	0.3784	1.0537	0.3294	0.18445	0.3012

2009.

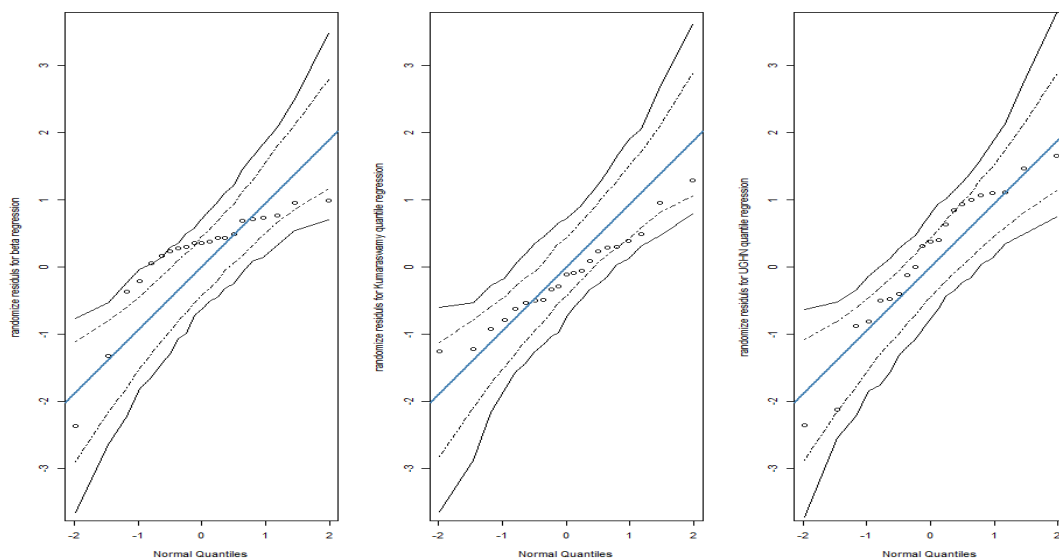


Figure 5.9. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2009.

CCRI/O 2010

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
-1.5554	-0.4526	0.2305	0.3997	1.2494

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	3.4407	0.7360	4.675	2.94e-06 ***
x1	0.1512	1.4076	0.107	0.914
x2	0.7285	1.7262	0.422	0.673
x3	0.6566	1.7380	0.378	0.706
x4	-0.8088	2.4886	-0.325	0.745
x5	0.4088	1.8112	0.226	0.821
x6	-1.4616	3.3885	-0.431	0.666

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	5.528	2.734	2.022	0.0432 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **94.04** on 8 Df

Pseudo R-squared: 0.1236

Number of iterations: 64 (BFGS) + 6 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1147 iterations

Return code 0: successful convergence

Log-Likelihood: **94.88526**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.26262	1.98833	4.156	3.25e-05 ***
gama1	-2.05006	3.04522	-0.673	0.500816
gama2	-1.24777	4.67801	-0.267	0.789676
gama3	0.05007	3.69039	0.014	0.989175
gama4	-6.61383	1.78799	-3.699	0.000216 ***
gama5	-0.91069	NA	NA	NA
gama6	2.74604	1.03458	2.654	0.007948 **
alpha	8.93586	0.79473	11.244	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1399 iterations
Return code 0: successful convergence
Log-Likelihood: **102.6122**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.91573	1.16091	7.680	1.59e-14 ***
gama1	-2.86907	0.89867	-3.193	0.001410 **
gama2	1.41586	0.59226	2.391	0.016821 *
gama3	7.96208	1.27691	6.235	4.51e-10 ***
gama4	-16.12520	1.64559	-9.799	< 2e-16 ***
gama5	-3.47569	0.89664	-3.876	0.000106 ***
gama6	2.28091	0.64687	3.526	0.000422 ***
alpha	0.34815	0.07259	4.796	1.62e-06 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.10. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2010.

2010 CCRI/O	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.33056	0.01515	2.0658	0.08513	0.44244	0.05498
Kumar Reg. Residuals	0.33811	0.01208	2.5001	0.05011	0.51506	0.03547
UGHN Reg. Residuals	0.21196	0.2626	0.903	0.4111	0.17071	0.334

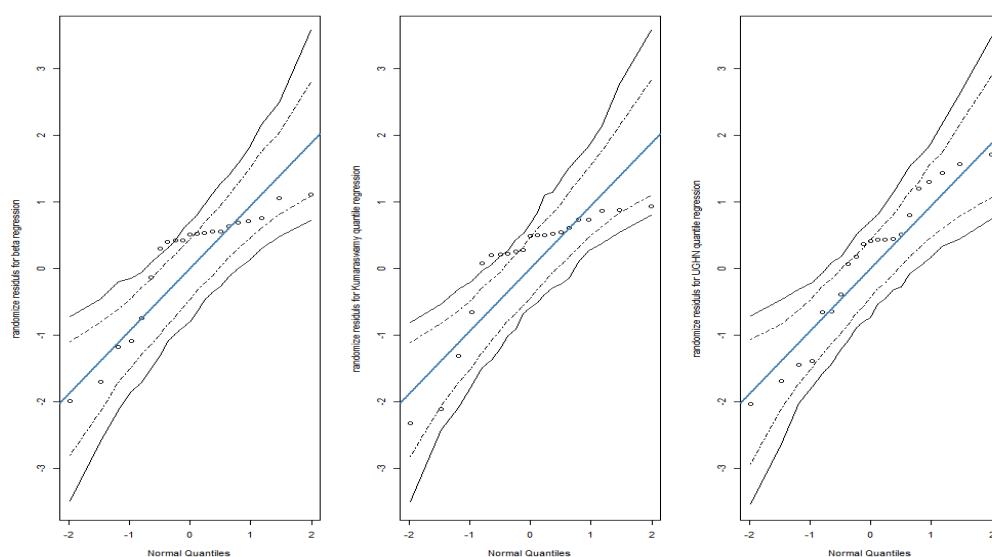


Figure 5.10. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2010.

BCCI 2010

THERE IS NO BETA REGRESSION

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 2277 iterations
Return code 10: degeneracy in Nelder-Mead simplex
Log-Likelihood: **120.616**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	5.77398	0.10795	53.49	<2e-16 ***
gama1	8.47173	0.25199	33.62	<2e-16 ***
gama2	31.22275	0.38541	81.01	<2e-16 ***
gama3	2.00564	0.05336	37.59	<2e-16 ***
gama4	22.19022	0.39475	56.21	<2e-16 ***
gama5	37.14035	0.33046	112.39	<2e-16 ***
gama6	-53.71923	0.04979	-1078.92	<2e-16 ***
alpha	26.49905	0.11485	230.73	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of (UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1631 iterations
Return code 0: successful convergence
Log-Likelihood: **144.2266**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.6234	0.3813	22.617	< 2e-16 ***
gama1	-0.3649	0.1305	-2.795	0.005186 **
gama2	1.5953	0.3318	4.808	1.52e-06 ***
gama3	2.2564	0.1433	15.749	< 2e-16 ***
gama4	-4.3723	0.6328	-6.909	4.88e-12 ***
gama5	-2.1589	0.7344	-2.940	0.003286 **
gama6	1.0242	0.4050	2.529	0.011439 *
alpha	0.8720	0.2470	3.530	0.000416 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.11. The results of testing the goodness of fit for the residual of the regression models for BCCI 2010.

2010 BCCI	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	---	---	---	---	---	---
Kumar Reg. Residuals	0.16605	0.5534	0.7968	0.4817	0.11791	0.5076
UGHN Reg. Residuals	0.3223	0.01929	2.9794	0.02849	0.5115	0.03623

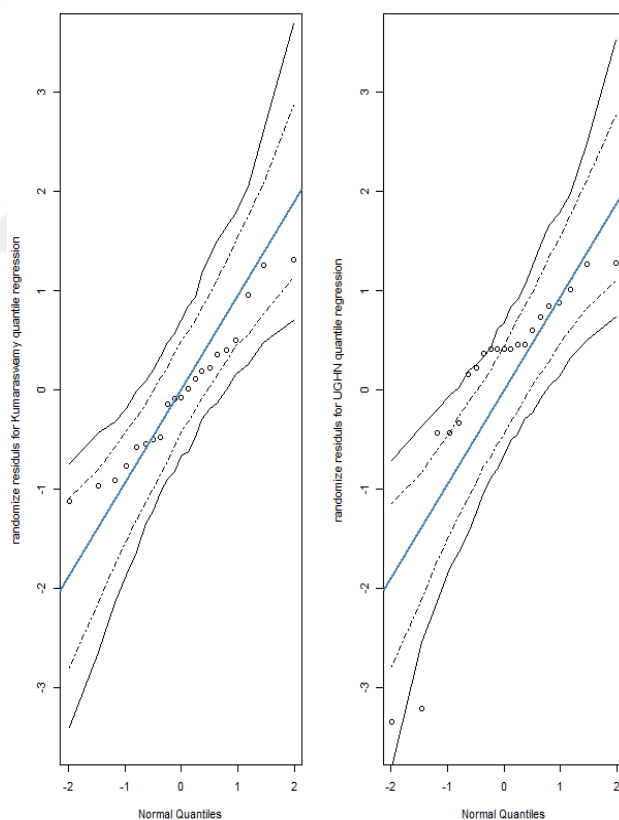


Figure 5.11. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2010.

BCCO 2010

THERE IS NO BETA REGRESSION

The results of Kumaraswamy regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 2543 iterations
Return code 0: successful convergence
Log-Likelihood: 120.4846
8 free parameters
Estimates:
      Estimate Std. error t value Pr(> t)
gama0   2.37808   0.12531   18.98 <2e-16 ***
gama1  12.47846   0.26153   47.71 <2e-16 ***
gama2  26.94826   0.06855  393.13 <2e-16 ***
gama3  23.51565   0.23534   99.92 <2e-16 ***
gama4  42.93811   0.20460  209.86 <2e-16 ***
gama5  23.72451   0.37771   62.81 <2e-16 ***
gama6 -82.28170   0.25866 -318.11 <2e-16 ***
alpha  23.47439   0.88344   26.57 <2e-16 ***
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of (UGHN) regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 1087 iterations
Return code 0: successful convergence
Log-Likelihood: 130.2922
8 free parameters
Estimates:
      Estimate Std. error t value Pr(> t)
gama0   7.9226   1.0563   7.500 6.37e-14 ***
gama1   1.1950   0.3472   3.442 0.000577 ***
gama2  -5.2628   0.3996 -13.170 < 2e-16 ***
gama3  -8.0659   0.3147 -25.629 < 2e-16 ***
gama4   5.8757   1.5689   3.745 0.000180 ***
gama5  -3.5133   0.4105  -8.560 < 2e-16 ***
gama6  11.7728   0.9878  11.919 < 2e-16 ***
alpha   0.3648   0.1057   3.450 0.000561 ***
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.12. The results of testing the goodness of fit for the residual of the regression models for BCCO 2010.

2010 BCCO	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	---	---	---	---	---	---
Kumar Reg. Residuals	0.17988	0.4528	1.0027	0.3548	0.14854	0.3965
UGHN Reg. Residuals	0.17987	0.4528	0.73623	0.5275	0.14793	0.3985

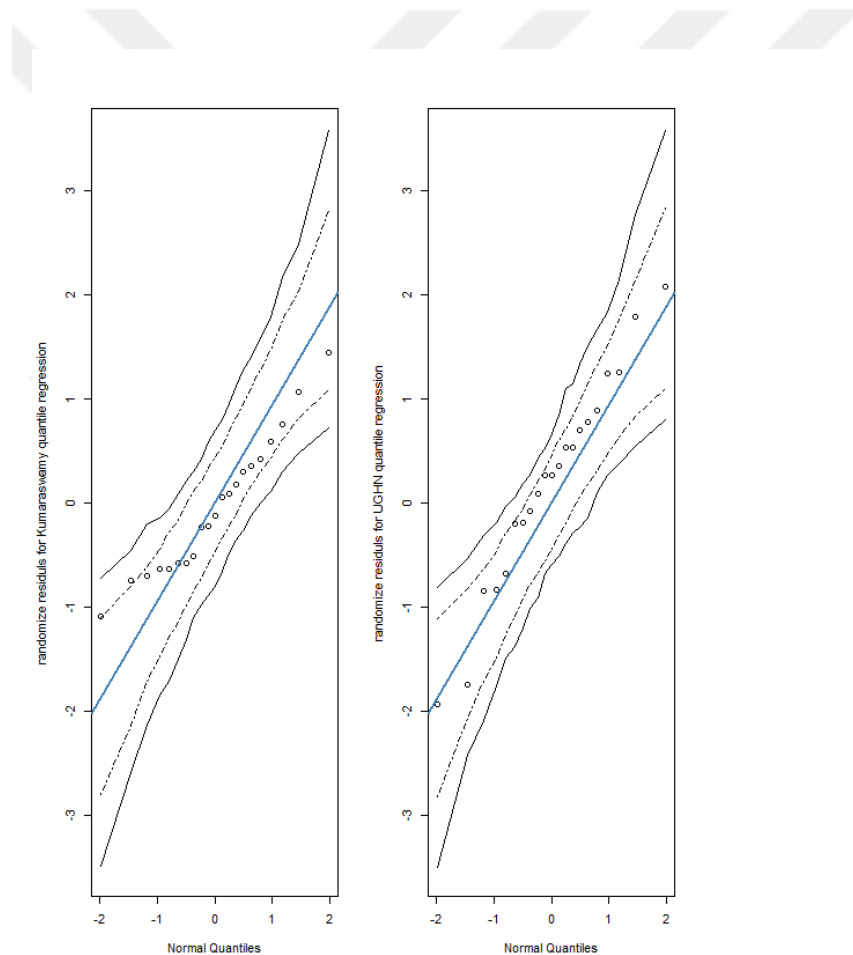


Figure 5.12. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2010.

CCRI/O 2011

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
-3.0710	-0.4608	-0.1141	0.7962	1.7669

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	5.1016	0.7459	6.840	7.93e-12 ***
x1	-0.1740	1.4657	-0.119	0.9055
x2	0.2498	2.0678	0.121	0.9038
x3	0.9571	1.6985	0.563	0.5731
x4	-5.9580	2.5917	-2.299	0.0215 *
x5	-1.2184	1.9967	-0.610	0.5417
x6	2.2784	2.9072	0.784	0.4332

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	21.21	10.90	1.946	0.0517 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **116.3** on 8 Df

Pseudo R-squared: 0.2133

Number of iterations: 265 (BFGS) + 37 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 2173 iterations

Return code 0: successful convergence

Log-Likelihood: **120.4813**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.2233	1.1973	6.868	6.51e-12 ***
gama1	1.3760	0.3194	4.308	1.65e-05 ***
gama2	7.9523	0.9647	8.243	< 2e-16 ***
gama3	7.8599	0.1444	54.441	< 2e-16 ***
gama4	-23.6564	1.0156	-23.293	< 2e-16 ***
gama5	-10.1592	1.2127	-8.378	< 2e-16 ***
gama6	2.8059	0.2843	9.871	< 2e-16 ***
alpha	37.9674	1.6492	23.022	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1231 iterations
Return code 0: successful convergence
Log-Likelihood: **131.0272**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	7.7596	0.2836	27.358	< 2e-16 ***
gama1	6.2596	0.4252	14.721	< 2e-16 ***
gama2	3.7623	0.4801	7.837	4.63e-15 ***
gama3	0.2722	0.1204	2.261	0.0237 *
gama4	2.6806	0.4969	5.395	6.87e-08 ***
gama5	-3.0046	0.2362	-12.722	< 2e-16 ***
gama6	-7.8879	0.2671	-29.531	< 2e-16 ***
alpha	0.8631	0.1470	5.871	4.32e-09 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.13. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2011.

2011 CCRI/O	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.24637	0.1313	1.1805	0.2746	0.25644	0.1805
Kumar Reg. Residuals	0.30929	0.02785	2.122	0.0794	0.41537	0.0649
UGHN Reg. Residuals	0.13729	0.7742	1.3015	0.2316	0.083164	0.6788

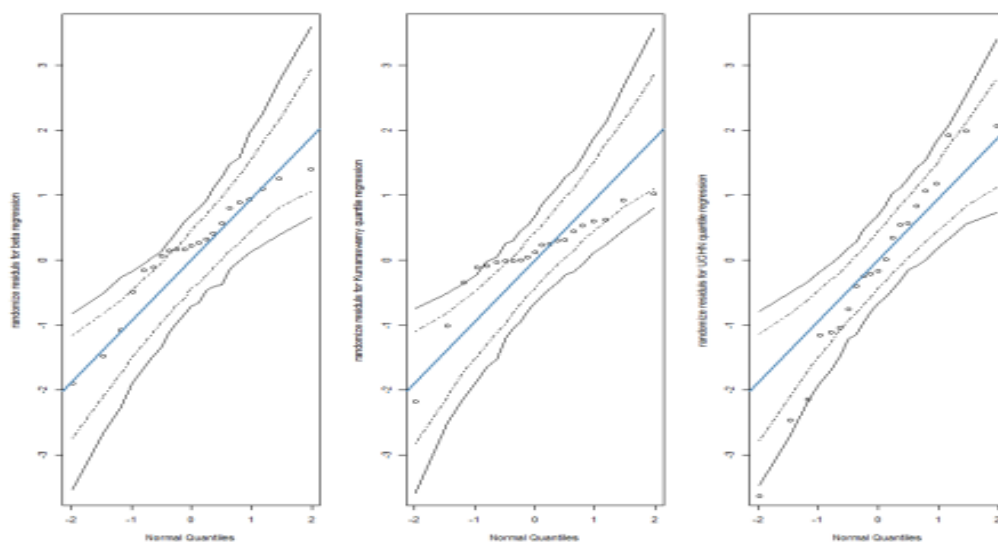


Figure 5.13. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2011.

BCCI 2011

THERE IS NO BETA REGRESSION

The results of Kumaraswamy regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 4757 iterations
Return code 0: successful convergence
Log-Likelihood: 131.3348
8 free parameters
Estimates:
      Estimate Std. error t value Pr(> t)
gama0  2.641848   0.117004   22.58 <2e-16 ***
gama1 25.246644   0.077402  326.18 <2e-16 ***
gama2 14.873692   0.172877   86.04 <2e-16 ***
gama3  8.168151   0.002139 3818.42 <2e-16 ***
gama4 26.712493   0.115740  230.80 <2e-16 ***
gama5  2.963556   0.076974   38.50 <2e-16 ***
gama6 -51.148125   0.172413 -296.66 <2e-16 ***
alpha 96.300203   0.050661 1900.87 <2e-16 ***
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of (UGHN) regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 1965 iterations
Return code 0: successful convergence
Log-Likelihood: 141.8764
8 free parameters
Estimates:
      Estimate Std. error t value  Pr(> t)
gama0  9.34306   0.46604  20.048 < 2e-16 ***
gama1 -6.37296   0.06640 -95.985 < 2e-16 ***
gama2 -6.77973   0.36955 -18.346 < 2e-16 ***
gama3  6.28698   0.41696  15.078 < 2e-16 ***
gama4 -1.06058   0.41052  -2.583 0.00978 **
gama5  5.26529   0.24412  21.568 < 2e-16 ***
gama6  2.73292   0.40104   6.815 9.46e-12 ***
alpha  0.40021   0.07387   5.418 6.03e-08 ***
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.14. The results of testing the goodness of fit for the residual of the regression models for BCCI 2011.

2011 BCCI	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	---	---	---	---	---	---
Kumar Reg. Residuals	0.17636	0.4775	1.0513	0.3306	0.13993	0.4246
UGHN Reg. Residuals	0.18509	0.4175	0.845	0.4482	0.18427	0.3016

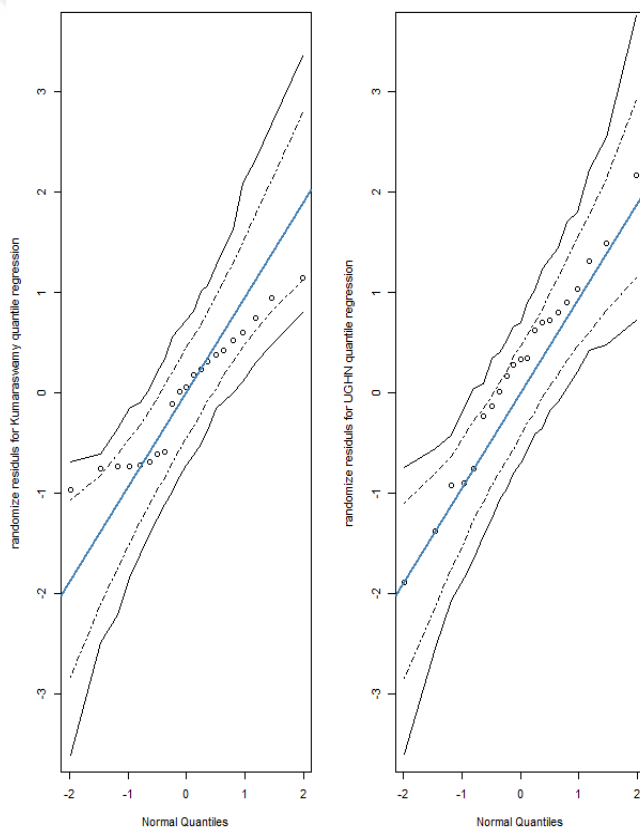


Figure 5.14. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2011.

BCCO 2011

THERE IS NO BETA REGRESSION

The results of Kumaraswamy regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 1689 iterations
Return code 0: successful convergence
Log-Likelihood: 130.5822
8 free parameters
Estimates:
      Estimate Std. error t value Pr(> t)
gama0    5.6741    2.3898   2.374 0.01758 *
gama1    6.3684    2.2751   2.799 0.00512 **
gama2   17.5514    1.6399  10.703 < 2e-16 ***
gama3    9.5121    2.9023   3.277 0.00105 **
gama4  -13.1900    0.9130 -14.446 < 2e-16 ***
gama5   -6.2695    0.5979 -10.485 < 2e-16 ***
gama6  -14.5694    0.9360 -15.566 < 2e-16 ***
alpha   61.1382    2.5974  23.538 < 2e-16 ***
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 1147 iterations
Return code 0: successful convergence
Log-Likelihood: 153.3382
8 free parameters
Estimates:
      Estimate Std. error t value  Pr(> t)
gama0   10.7657    0.4885  22.038 < 2e-16 ***
gama1   -5.0210    0.2065 -24.314 < 2e-16 ***
gama2   -8.0003    0.6634 -12.060 < 2e-16 ***
gama3   -3.7649    0.3213 -11.719 < 2e-16 ***
gama4    3.9063    0.6953   5.618 1.93e-08 ***
gama5    4.6501    0.8137   5.715 1.10e-08 ***
gama6    7.8838    0.5794  13.608 < 2e-16 ***
alpha    0.7135    0.2053   3.476 0.000509 ***
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.15. The results of testing the goodness of fit for the residual of the regression models for BCCO 2011.

2011 BCCO	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	---	---	---	---	---	---
Kumar Reg. Residuals	0.29368	0.04235	2.6098	0.04396	0.51427	0.03563
UGHN Reg. Residuals	0.16251	0.5804	0.76411	0.5059	0.11918	0.5023

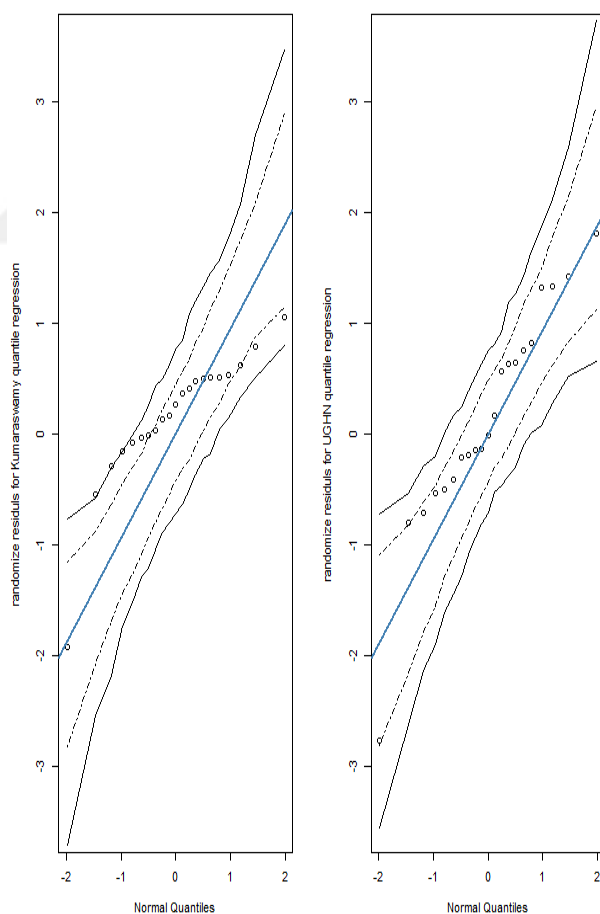


Figure 5.15. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2011.

CCRI/O 2012

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
-1.3580	-0.2590	-0.0187	0.3976	1.3433

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.1603	0.7495	5.550	2.85e-08 ***
x1	1.3086	1.4852	0.881	0.378
x2	0.1259	2.5387	0.050	0.960
x3	-1.5398	2.0677	-0.745	0.456
x4	2.3927	2.8848	0.829	0.407
x5	0.4534	1.9093	0.237	0.812
x6	-1.4130	3.0374	-0.465	0.642

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	14.789	7.665	1.929	0.0537 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **114.4** on 8 Df

Pseudo R-squared: 0.3482

Number of iterations: 196 (BFGS) + 6 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1893 iterations

Return code 0: successful convergence

Log-Likelihood: **114.4577**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	5.522	1.515	3.644	0.000268 ***
gama1	8.427	2.596	3.246	0.001171 **
gama2	5.470	1.306	4.188	2.81e-05 ***
gama3	-4.476	1.463	-3.061	0.002207 **
gama4	7.551	1.843	4.098	4.16e-05 ***
gama5	-3.576	1.676	-2.133	0.032912 *
gama6	-7.906	1.610	-4.912	9.02e-07 ***
alpha	18.752	1.049	17.874	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 2547 iterations
Return code 0: successful convergence
Log-Likelihood: **136.1839**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	9.7476	0.3018	32.293	< 2e-16 ***
gama1	-1.2343	0.3102	-3.979	6.91e-05 ***
gama2	-3.5970	0.5903	-6.093	1.11e-09 ***
gama3	-3.7344	0.6519	-5.729	1.01e-08 ***
gama4	1.9965	0.5486	3.639	0.000273 ***
gama5	1.2436	0.3945	3.153	0.001618 **
gama6	4.3897	0.5230	8.393	< 2e-16 ***
alpha	1.0253	0.2386	4.298	1.73e-05 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.16. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2012.

2012 CCRI/O	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.3537	0.007431	2.6183	0.04352	0.57797	0.0244
Kumar Reg. Residuals	0.32968	0.01555	2.2347	0.06911	0.47273	0.04574
UGHN Reg. Residuals	0.2391	0.1534	2.7024	0.0394	0.28762	0.1463

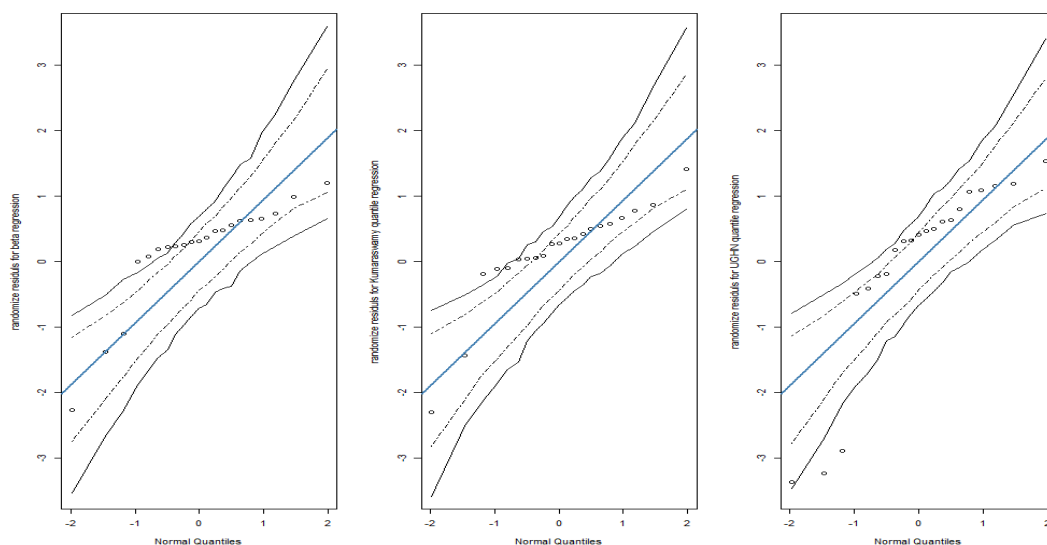


Figure 5.16. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2012.

BCCI 2012

THERE IS NO BETA REGRESSION

The results of Kumaraswamy regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 1799 iterations
Return code 0: successful convergence
Log-Likelihood: 121.1465
8 free parameters
Estimates:
      Estimate Std. error t value Pr(> t)
gama0    4.4086    1.1416   3.862 0.000113 ***
gama1    5.0506    1.9526   2.587 0.009694 **
gama2    9.0037    0.6984  12.892 < 2e-16 ***
gama3    2.9130    0.4110   7.088 1.36e-12 ***
gama4   11.3828    2.1878   5.203 1.96e-07 ***
gama5    9.7101    0.8572  11.328 < 2e-16 ***
gama6   -22.6138    0.8341 -27.113 < 2e-16 ***
alpha   31.6472    1.5714  20.140 < 2e-16 ***
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 2939 iterations
Return code 0: successful convergence
Log-Likelihood: 147.3611
8 free parameters
Estimates:
      Estimate Std. error t value Pr(> t)
gama0    9.4546    0.4397  21.504 < 2e-16 ***
gama1   -2.0730    0.3761  -5.512 3.55e-08 ***
gama2   -1.2338    0.2827  -4.365 1.27e-05 ***
gama3   -0.5642    0.1676  -3.367 0.00076 ***
gama4   -2.7790    0.4722  -5.885 3.97e-09 ***
gama5   -1.5582    0.5259  -2.963 0.00305 **
gama6    5.9268    0.4786  12.385 < 2e-16 ***
alpha    0.9606    0.1839   5.223 1.76e-07 ***
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.17. The results of testing the goodness of fit for the residual of the regression models for BCCI 2012.

2012 BCCI	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	---	---	---	---	---	---
Kumar Reg. Residuals	0.306	0.03048	2.112	0.08038	0.40457	0.06938
UGHN Reg. Residuals	0.27324	0.07081	2.7461	0.03742	0.42893	0.05971

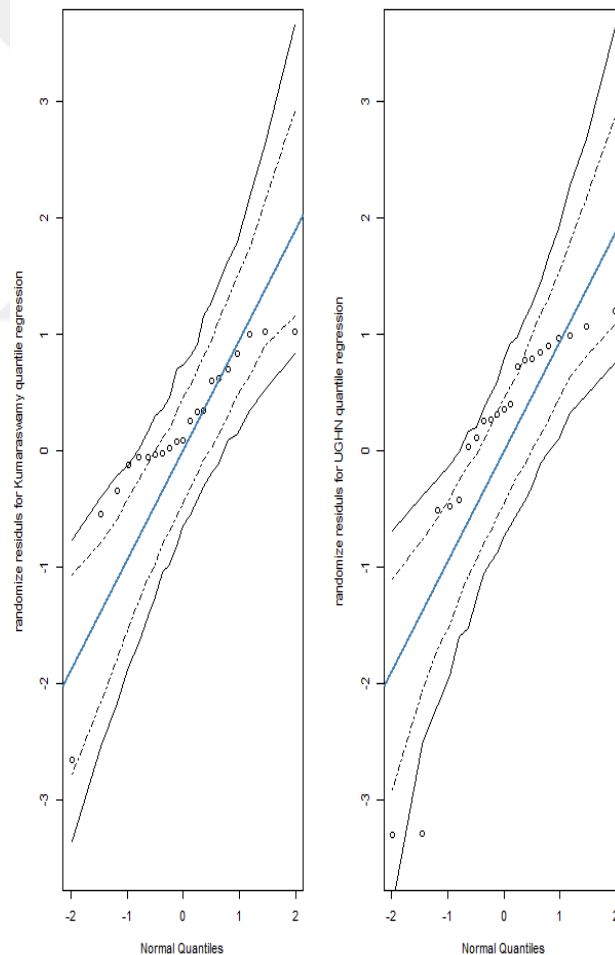


Figure 5.17. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2012.

BCCO

2012

THERE IS NO BETA REGRESSION

The results of Kumaraswamy regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 1235 iterations
Return code 0: successful convergence
Log-Likelihood: 120.7059
8 free parameters
Estimates:
      Estimate Std. error t value  Pr(> t)
gama0    4.5581    0.6607   6.899 5.23e-12 ***
gama1    4.9330    1.5896   3.103 0.001913 **
gama2    7.0601    2.0775   3.398 0.000678 ***
gama3    2.1556    0.6099   3.534 0.000409 ***
gama4   11.1823    0.8815  12.686 < 2e-16 ***
gama5    8.1690    1.2252   6.668 2.60e-11 ***
gama6  -20.0374    0.6688 -29.961 < 2e-16 ***
alpha   26.2222    8.8766   2.954 0.003136 **
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 1357 iterations
Return code 0: successful convergence
Log-Likelihood: 132.7464
8 free parameters
Estimates:
      Estimate Std. error t value  Pr(> t)
gama0  12.25906    0.17526  69.947 < 2e-16 ***
gama1   -7.63105    0.47991 -15.901 < 2e-16 ***
gama2 -14.67306    0.57900 -25.342 < 2e-16 ***
gama3 -11.55829    0.21662 -53.358 < 2e-16 ***
gama4    3.17285    0.34431   9.215 < 2e-16 ***
gama5    4.23459    1.04662   4.046 5.21e-05 ***
gama6   20.81997    0.25871  80.476 < 2e-16 ***
alpha    0.37588    0.06012   6.253 4.03e-10 ***
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.18. The results of testing the goodness of fit for the residual of the regression models for BCCO 2012.

2012 BCCO	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	---	---	---	---	---	---
Kumar Reg. Residuals	0.30919	0.02793	2.4648	0.05228	0.48483	0.04252
UGHN Reg. Residuals	0.19623	0.3475	0.89038	0.4189	0.18052	0.3102

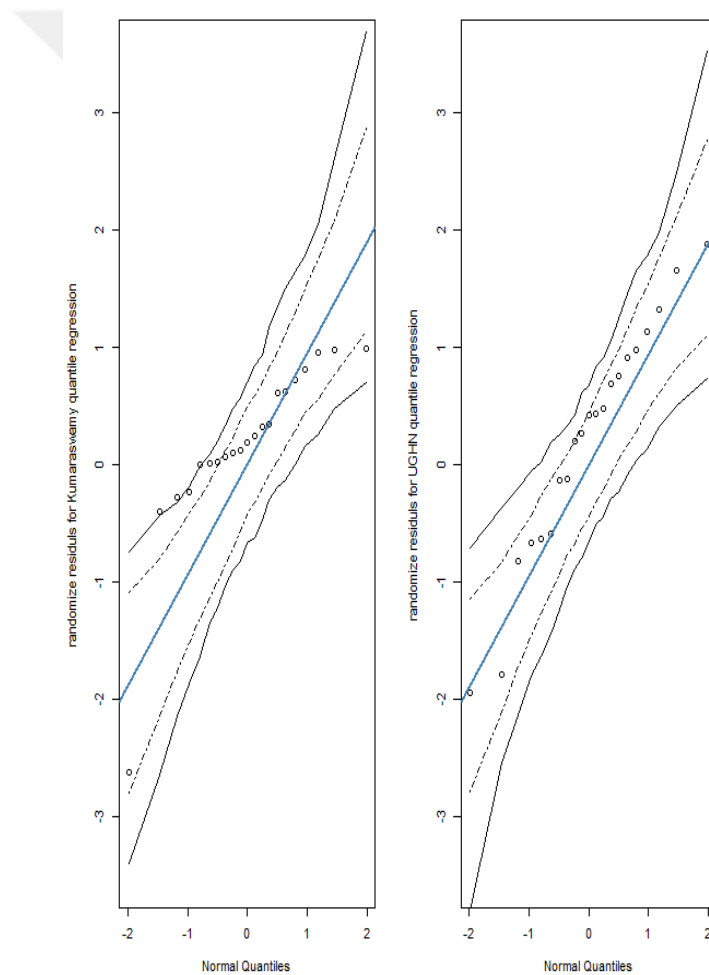


Figure 5.18. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2012.

CCRI/O 2013

THERE IS NO BETA REGRESSION

The results of Kumaraswamy regression analysis

```

-----
Maximum Likelihood estimation
Nelder-Mead maximization, 1885 iterations
Return code 0: successful convergence
Log-Likelihood: 107.2154
8 free parameters
Estimates:
      Estimate Std. error  t value Pr(> t)
gama0    2.71343    0.27224    9.967 <2e-16 ***
gama1   21.01689    0.02321   905.425 <2e-16 ***
gama2   17.46238    0.13869   125.913 <2e-16 ***
gama3   -1.69118    0.14933   -11.325 <2e-16 ***
gama4   30.25162    0.27326   110.705 <2e-16 ***
gama5    2.84330    0.14170    20.065 <2e-16 ***
gama6  -45.18084    0.14581  -309.860 <2e-16 ***
alpha   27.16260    0.15246   178.167 <2e-16 ***

```

```

---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
-----

```

The results of (UGHN) regression analysis

```

-----
Maximum Likelihood estimation
Nelder-Mead maximization, 2467 iterations
Return code 0: successful convergence
Log-Likelihood: 117.7409
8 free parameters
Estimates:
      Estimate Std. error t value  Pr(> t)
gama0    9.3722    0.2041  45.922 < 2e-16 ***
gama1    1.9595    0.7408   2.645 0.008165 **
gama2   -4.1646    0.1457 -28.588 < 2e-16 ***
gama3   -9.8390    1.1576  -8.499 < 2e-16 ***
gama4    6.2071    1.3513   4.594 4.36e-06 ***
gama5    2.0336    0.6395   3.180 0.001472 **
gama6    4.6854    1.2936   3.622 0.000292 ***
alpha    0.6003    0.1086   5.527 3.25e-08 ***

```

```

---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

Table 5.19. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2013.

2013 CCRI/O	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	---	---	---	---	---	---
Kumar Reg. Residuals	0.14893	0.686	0.55282	0.6916	0.079901	0.6975
UGHN Reg. Residuals	0.18215	0.4372	0.8558	0.441	0.13039	0.4584

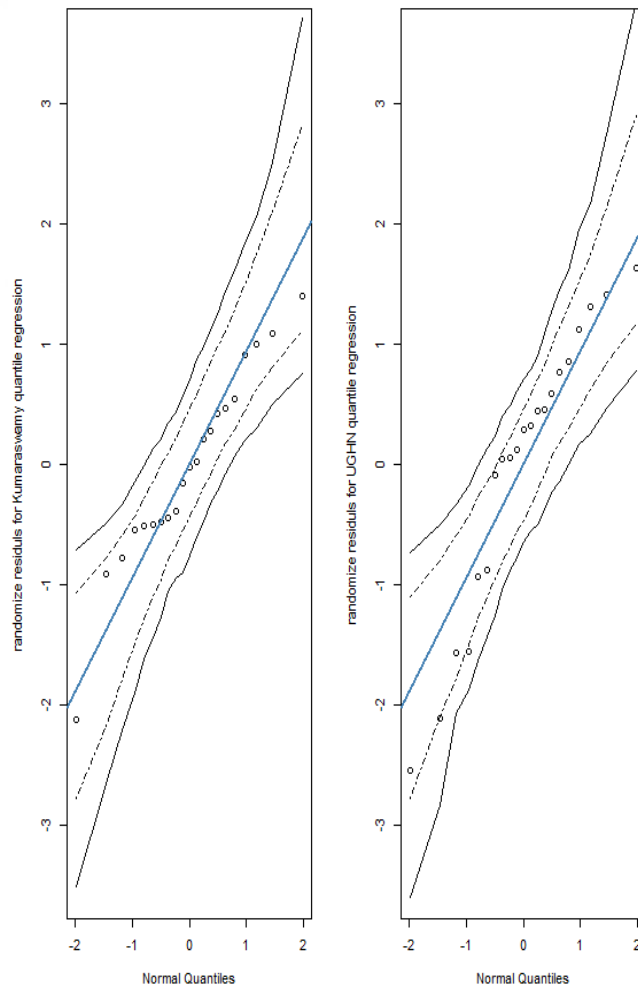


Figure 5.19. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2013.

BCCI 2013

THERE IS NO BETA REGRESSION

The results of Kumaraswamy regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 1237 iterations
Return code 0: successful convergence
Log-Likelihood: 117.1161
8 free parameters
Estimates:
      Estimate Std. error  t value Pr(> t)
gama0    3.55250    0.13317   26.677 < 2e-16 ***
gama1   19.40475    0.19230  100.911 < 2e-16 ***
gama2   15.66199    0.27469   57.017 < 2e-16 ***
gama3   -1.40503    0.20430   -6.877 6.1e-12 ***
gama4    1.59600    0.06702   23.814 < 2e-16 ***
gama5  -18.23658    0.21093  -86.458 < 2e-16 ***
gama6   -9.42042    0.02567 -366.956 < 2e-16 ***
alpha   28.26104    0.42655   66.255 < 2e-16 ***
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of (UGHN) regression analysis

```
-----
Maximum Likelihood estimation
Nelder-Mead maximization, 1607 iterations
Return code 0: successful convergence
Log-Likelihood: 129.6094
8 free parameters
Estimates:
      Estimate Std. error t value  Pr(> t)
gama0    8.9250    0.5303  16.830 < 2e-16 ***
gama1   -4.4045    0.6089  -7.233 4.71e-13 ***
gama2   -3.0205    0.6793  -4.446 8.74e-06 ***
gama3    3.7240    0.9681   3.847 0.00012 ***
gama4   -2.1407    0.0614 -34.865 < 2e-16 ***
gama5    1.6932    0.7703   2.198 0.02796 *
gama6    2.8596    0.3884   7.362 1.81e-13 ***
alpha    0.5129    0.1223   4.194 2.74e-05 ***
---
```

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.20. The results of testing the goodness of fit for the residual of the regression models for BCCI 2013.

2013 BCCI	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	---	---	---	---	---	---
Kumar Reg. Residuals	0.18701	0.4049	1.0336	0.3392	0.17252	0.3294
UGHN Reg. Residuals	0.206	0.2928	2.022	0.08991	0.32114	0.1175

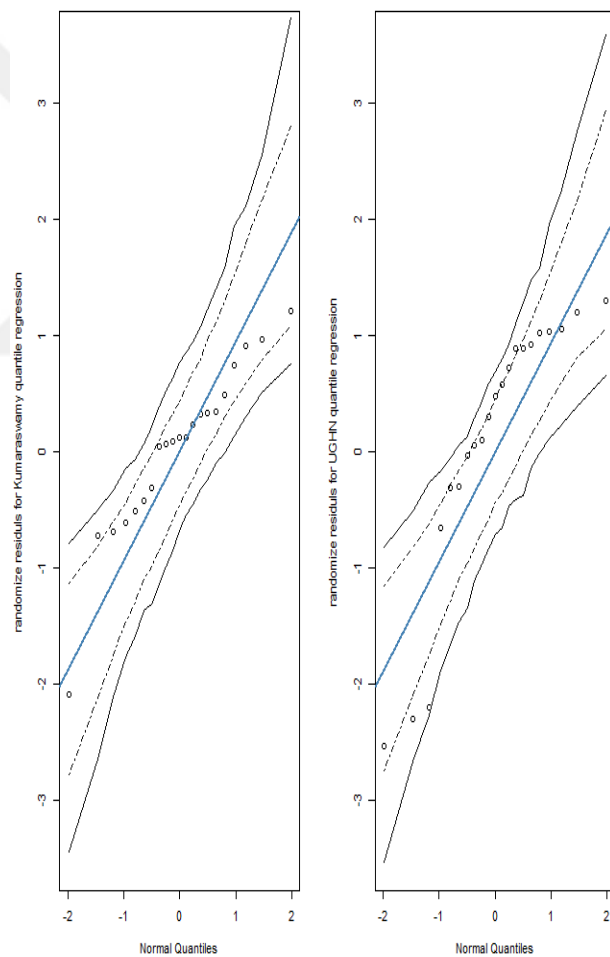


Figure 5.20. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2013.

BCCO 2013

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-1.6297	-0.2649	0.0375	0.4984	1.2179

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	3.9594	0.7748	5.110	3.21e-07 ***
x1	1.7803	1.3365	1.332	0.183
x2	1.4542	1.9871	0.732	0.464
x3	-0.4699	1.9967	-0.235	0.814
x4	0.9289	2.2120	0.420	0.675
x5	-0.7347	1.3361	-0.550	0.582
x6	-1.9973	2.9222	-0.683	0.494

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	14.663	7.608	1.927	0.0539 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **114.8** on 8 Df

Pseudo R-squared: 0.3498

Number of iterations: 108 (BFGS) + 8 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 2603 iterations

Return code 0: successful convergence

Log-Likelihood: **115.4359**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	3.83191	0.19480	19.67	<2e-16 ***
gama1	18.32841	0.19793	92.60	<2e-16 ***
gama2	13.16741	0.09580	137.44	<2e-16 ***
gama3	-2.34106	0.03102	-75.47	<2e-16 ***
gama4	-0.50260	0.04286	-11.73	<2e-16 ***
gama5	-15.73241	0.13793	-114.06	<2e-16 ***
gama6	-7.18725	0.25822	-27.83	<2e-16 ***
alpha	15.02323	0.34236	43.88	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1747 iterations
Return code 0: successful convergence
Log-Likelihood: **119.7175**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	11.12084	1.15640	9.617	< 2e-16 ***
gama1	4.66627	0.30635	15.232	< 2e-16 ***
gama2	-6.75102	0.63742	-10.591	< 2e-16 ***
gama3	-9.96792	0.50916	-19.577	< 2e-16 ***
gama4	9.54834	1.21752	7.842	4.42e-15 ***
gama5	-1.77082	0.66605	-2.659	0.00784 **
gama6	-2.40710	1.12963	-2.131	0.03310 *
alpha	0.23842	0.05343	4.462	8.11e-06 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.21 The results of testing the goodness of fit for the residual of the regression models for BCCO 2013.

2013 BCCO	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.34202	0.01072	2.6903	0.03996	0.56674	0.02608
Kumar Reg. Residuals	0.22483	0.2053	1.4576	0.187	0.2548	0.1825
UGHN Reg. Residuals	0.23371	0.1716	1.5326	0.1691	0.25805	0.1785

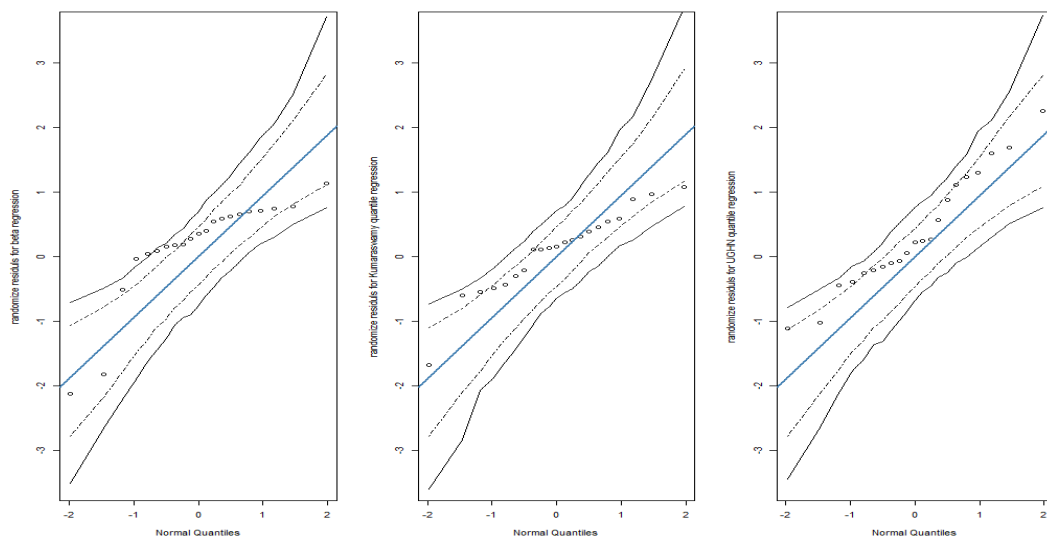


Figure 5.21. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2013.

CCRI/O 2014

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-2.5361	-0.4745	-0.1913	0.4675	2.4757

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	5.17542	0.74588	6.939	3.96e-12 ***
x1	3.30608	1.28707	2.569	0.0102 *
x2	0.34113	1.71855	0.198	0.8427
x3	-3.92476	1.73893	-2.257	0.0240 *
x4	2.97267	1.77469	1.675	0.0939 .
x5	0.02679	0.89182	0.030	0.9760
x6	-2.08280	2.55058	-0.817	0.4142

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	32.98	15.90	2.075	0.038 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **114.3** on 8 Df

Pseudo R-squared: 0.4212

Number of iterations: 192 (BFGS) + 19 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1545 iterations

Return code 0: successful convergence

Log-Likelihood: **116.3489**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	7.1726	0.4377	16.389	<2e-16 ***
gama1	15.9805	0.6103	26.184	<2e-16 ***
gama2	7.0825	0.6320	11.207	<2e-16 ***
gama3	-10.3612	0.7759	-13.354	<2e-16 ***
gama4	3.1145	0.3364	9.259	<2e-16 ***
gama5	-5.9468	0.4347	-13.679	<2e-16 ***
gama6	-6.3292	0.4382	-14.445	<2e-16 ***
alpha	51.8364	1.8692	27.731	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 2695 iterations
Return code 0: successful convergence
Log-Likelihood: **130.729**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.3595	0.7119	11.743	< 2e-16 ***
gama1	4.7231	0.9273	5.093	3.52e-07 ***
gama2	2.9346	0.6228	4.712	2.45e-06 ***
gama3	-2.2361	0.3405	-6.568	5.11e-11 ***
gama4	2.7875	0.5525	5.045	4.53e-07 ***
gama5	-1.2257	0.5121	-2.394	0.0167 *
gama6	-6.2394	0.9923	-6.288	3.21e-10 ***
alpha	0.5828	0.1164	5.007	5.52e-07 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.22. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2014.

2014 CCRI/O	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.22672	0.1977	0.81361	0.4697	0.16897	0.3385
Kumar Reg. Residuals	0.25971	0.09742	1.4358	0.1926	0.26648	0.1686
UGHN Reg. Residuals	0.16256	0.5801	0.51467	0.7299	0.090192	0.6399

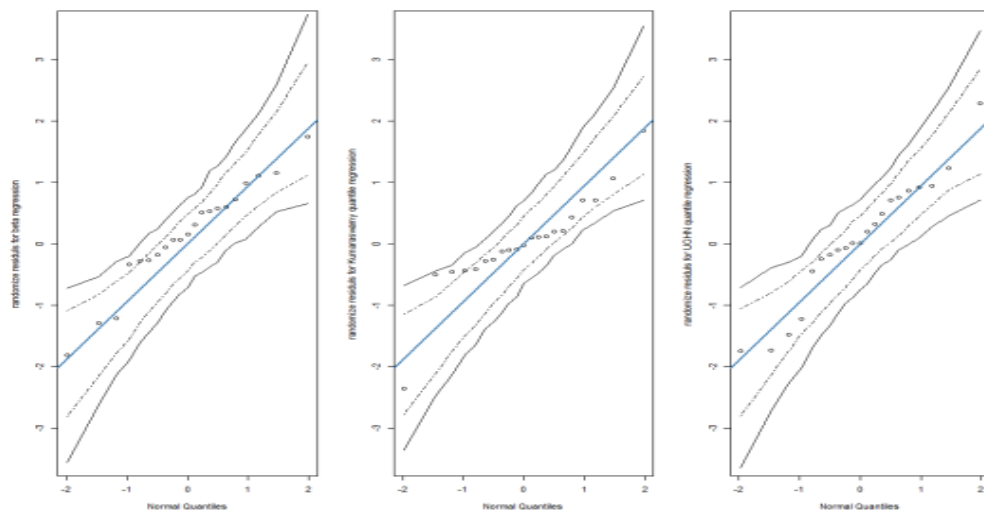


Figure 5.22. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2014.

BCCI 2014

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-3.0697	-0.5618	-0.3644	0.9312	1.5217

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	5.9559	0.7762	7.673	1.68e-14	***
x1	2.7723	1.2699	2.183	0.029029	*
x2	-1.4260	1.7169	-0.831	0.406220	
x3	-5.8276	1.6701	-3.489	0.000484	***
x4	4.3685	1.7516	2.494	0.012632	*
x5	1.3798	0.9074	1.521	0.128368	
x6	-0.2926	2.5696	-0.114	0.909343	

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	50.03	24.91	2.009	0.0446

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **123.7** on 8 Df

Pseudo R-squared: 0.4031

Number of iterations: 415 (BFGS) + 36 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 3749 iterations

Return code 0: successful convergence

Log-Likelihood: **122.3633**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)	
gama0	9.5586	0.7920	12.069	<2e-16	***
gama1	0.2585	0.1228	2.105	0.0353	*
gama2	-8.6553	0.9374	-9.233	<2e-16	***
gama3	-13.9877	0.9724	-14.385	<2e-16	***
gama4	10.0037	0.4227	23.664	<2e-16	***
gama5	8.3163	0.9543	8.715	<2e-16	***
gama6	6.6166	0.5114	12.938	<2e-16	***
alpha	16.7782	0.9947	16.868	<2e-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 2111 iterations
Return code 0: successful convergence
Log-Likelihood: **136.2196**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	6.81063	0.69859	9.749	< 2e-16 ***
gama3	1.60613	0.51668	3.109	0.00188 **
gama2	3.42926	0.24683	13.893	< 2e-16 ***
gama3	4.68070	0.29470	15.883	< 2e-16 ***
gama4	-9.82744	0.08674	-113.292	< 2e-16 ***
gama5	-2.16778	0.42769	-5.069	4.01e-07 ***
gama6	3.10604	0.65988	4.707	2.51e-06 ***
alpha	0.45444	0.09691	4.689	2.74e-06 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.23. The results of testing the goodness of fit for the residual of the regression models for BCCI 2014.

2014 BCCI	One-sample kolmogorov-Smir nov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.25745	0.1026	1.1798	0.2748	0.22667	0.2218
Kumar Reg. Residuals	0.34406	0.01006	3.6422	0.01334	0.7469	0.00907
UGHN Reg. Residuals	0.20072	0.3216	0.77205	0.4999	0.16494	0.3491

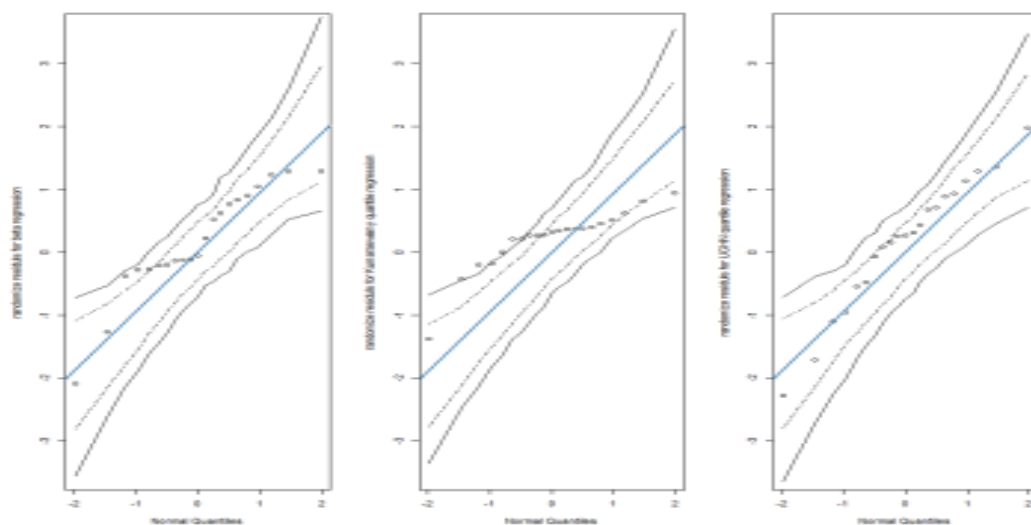


Figure 5.23. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2014.

BCCO 2014

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-3.1997	-0.5904	-0.3912	0.9472	1.5771

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	6.1732	0.7698	8.019	1.06e-15 ***
x1	2.9023	1.2610	2.302	0.021361 *
x2	-1.5642	1.7029	-0.919	0.358333
x3	-6.2119	1.6246	-3.824	0.000132 ***
x4	4.6378	1.7294	2.682	0.007325 **
x5	1.4733	0.9047	1.628	0.103446
x6	-0.2078	2.5544	-0.081	0.935153

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	61.79	30.50	2.026	0.0427 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **124.4** on 8 Df

Pseudo R-squared: 0.4049

Number of iterations: 499 (BFGS) + 36 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1517 iterations

Return code 0: successful convergence

Log-Likelihood: **127.524**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	9.41046	0.13295	70.781	< 2e-16 ***
gama1	12.08779	0.02040	592.621	< 2e-16 ***
gama2	-6.01690	0.08942	-67.292	< 2e-16 ***
gama3	-10.35105	0.33827	-30.600	< 2e-16 ***
gama4	-11.00117	0.20465	-53.757	< 2e-16 ***
gama5	23.09578	0.22729	101.613	< 2e-16 ***
gama6	1.74872	0.33085	5.286	1.25e-07 ***
alpha	95.92852	0.48538	197.634	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1507 iterations
Return code 0: successful convergence
Log-Likelihood: **138.9181**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	9.37591	0.93128	10.068	< 2e-16 ***
gama1	-4.78598	0.51008	-9.383	< 2e-16 ***
gama2	2.34894	0.02638	89.041	< 2e-16 ***
gama3	6.71282	0.79882	8.403	< 2e-16 ***
gama4	-5.98094	0.45467	-13.154	< 2e-16 ***
gama5	-1.37074	0.63135	-2.171	0.0299 *
gama6	-0.59190	0.13929	-4.249	2.14e-05 ***
alpha	0.50735	0.10193	4.977	6.45e-07 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.24. The results of testing the goodness of fit for the residual of the regression models for BCCO 2014.

2014 BCCO	One-sample kolmogorov-Smir nov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.23743	0.1589	1.0469	0.3327	0.19535	0.2779
Kumar Reg. Residuals	0.17641	0.4772	0.84404	0.4488	0.13538	0.4403
UGHN Reg. Residuals	0.21257	0.2597	1.097	0.3094	0.19775	0.273

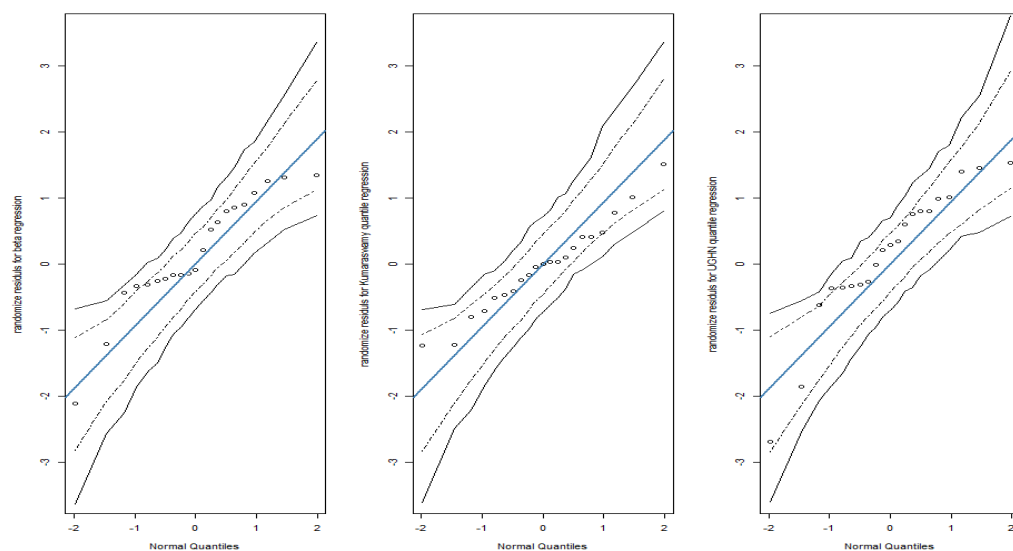


Figure 5.24. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2014.

CCRI/O 2015

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-2.8670	-0.5300	0.0672	0.4460	2.2468

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	7.5228	0.7086	10.617	<2e-16 ***
x1	0.7034	1.2819	0.549	0.5832
x2	0.7407	1.6955	0.437	0.6622
x3	0.9526	1.8789	0.507	0.6121
x4	-5.3868	1.7432	-3.090	0.0020 **
x5	-2.7073	1.4488	-1.869	0.0617 .
x6	1.2961	2.3127	0.560	0.5752

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	422.7	182.0	2.322	0.0202 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **133.4** on 8 Df

Pseudo R-squared: 0.3339

Number of iterations: 4306 (BFGS) + 22 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1817 iterations

Return code 0: successful convergence

Log-Likelihood: **129.1967**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	12.0706	0.8683	13.902	< 2e-16 ***
gama1	-8.9875	1.2260	-7.331	2.29e-13 ***
gama2	-6.6881	0.6804	-9.829	< 2e-16 ***
gama3	1.6351	0.6046	2.704	0.00684 **
gama4	-9.4465	0.3009	-31.397	< 2e-16 ***
gama5	-4.9752	0.5592	-8.896	< 2e-16 ***
gama6	14.5512	0.9088	16.012	< 2e-16 ***
alpha	125.1739	2.4242	51.634	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1481 iterations
Return code 0: successful convergence
Log-Likelihood: **150.9891**
8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.5749	0.4049	21.180	< 2e-16 ***
gama1	0.9269	0.3705	2.501	0.0124 *
gama2	2.0310	0.4819	4.214	2.51e-05 ***
gama3	2.4462	0.5318	4.600	4.22e-06 ***
gama4	-6.4947	0.8980	-7.232	4.76e-13 ***
gama5	-3.9282	0.5859	-6.704	2.03e-11 ***
gama6	1.3523	0.3257	4.152	3.29e-05 ***
alpha	0.8377	0.1611	5.200	1.99e-07 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.25. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2015.

2015 CCRI/O	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.17611	0.4793	0.76571	0.5047	0.14128	0.42
Kumar Reg. Residuals	0.23885	0.1542	1.8308	0.1145	0.32154	0.1172
UGHN Reg. Residuals	0.1687	0.5335	0.63312	0.6152	0.126	0.475

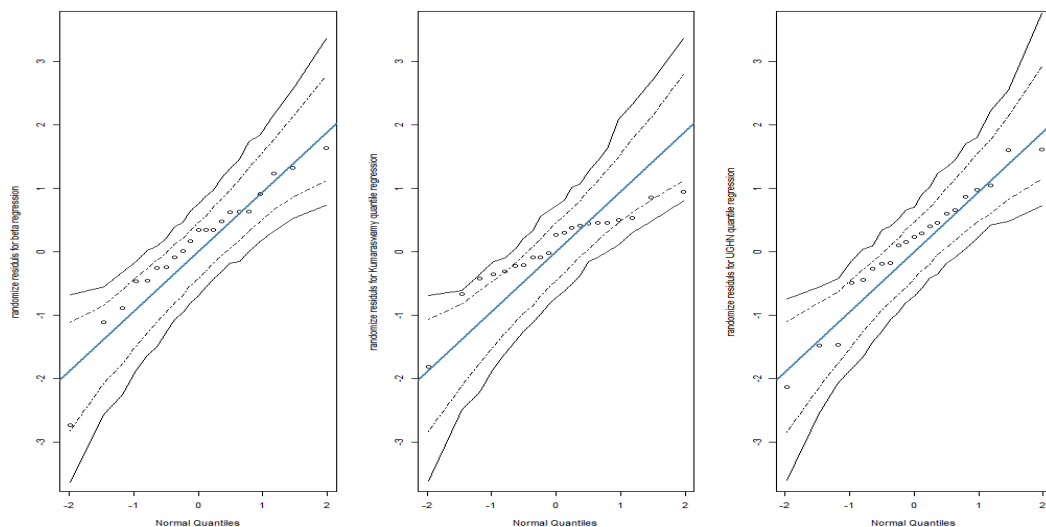


Figure 5.25. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2015.

BCCI 2015

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
5.2376	5.5161	5.7041	6.1959	14.9086

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	9.210e+00	9.800e-16	9.398e+15	< 2e-16 ***
x1	-4.654e-16	1.975e-15	-2.360e-01	0.814
x2	-3.219e-15	2.699e-15	-1.193e+00	0.233
x3	-4.359e-15	2.992e-15	-1.457e+00	0.145
x4	-2.761e-15	3.280e-15	-8.420e-01	0.400
x5	1.415e-14	2.437e-15	5.804e+00	6.47e-09 ***
x6	6.083e-15	3.852e-15	1.579e+00	0.114

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	4.823e+33	5.276e+23	9.14e+09	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **-8.717e+05** on 8 Df

Number of iterations: 1 (BFGS) + 1 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 2431 iterations

Return code 0: successful convergence

Log-Likelihood: **151.5894**

Eight free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	10.70892	0.17895	59.844	< 2e-16 ***
gama1	-9.31745	0.23427	-39.773	< 2e-16 ***
gama2	-5.01489	0.11427	-43.887	< 2e-16 ***
gama3	2.92249	0.29297	9.975	< 2e-16 ***
gama4	-12.01973	0.02761	-435.313	< 2e-16 ***
gama5	-13.02134	0.18127	-71.834	< 2e-16 ***
gama6	24.84683	0.24883	99.854	< 2e-16 ***
alpha	1756.11826	348.19976	5.043	4.57e-07 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 2719 iterations
Return code 0: successful convergence
Log-Likelihood: **177.4027**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.45933	0.14126	59.884	< 2e-16 ***
gama1	-1.13543	0.48235	-2.354	0.0186 *
gama2	1.65835	0.42629	3.890	0.0001 ***
gama3	4.57324	0.44743	10.221	< 2e-16 ***
gama4	-3.51586	0.34631	-10.152	< 2e-16 ***
gama5	-1.55236	0.12299	-12.622	< 2e-16 ***
gama6	-0.34302	0.02912	-11.780	< 2e-16 ***
alpha	1.73629	0.23903	7.264	3.76e-13 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.26. The results of testing the goodness of fit for the residual of the regression models for BCCI 2015.

2015 BCCI	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.5	5.507e-05	8.1122	0.0001287	1.75	2.233e-05
Kumar Reg. Residuals	0.18323	0.4299	0.90209	0.4116	0.11263	0.5303
UGHN Reg. Residuals	0.13815	0.768	0.29567	0.9408	0.039754	0.9386

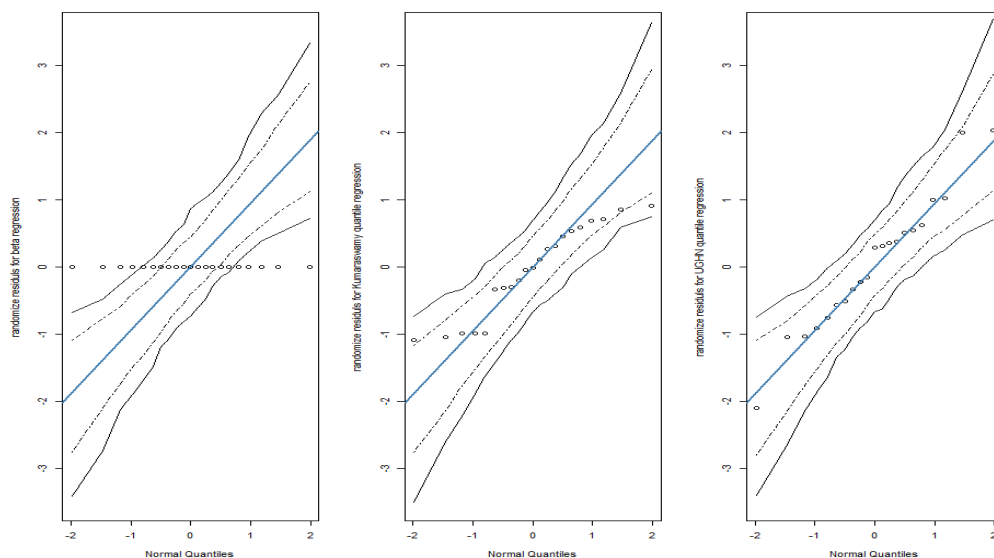


Figure 5.26. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2015.

BCCO 2015

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
5.2376	5.5161	5.7041	6.1959	14.9086

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	9.210e+00	9.800e-16	9.398e+15	< 2e-16 ***
x1	-4.654e-16	1.975e-15	-2.360e-01	0.814
x2	-3.219e-15	2.699e-15	-1.193e+00	0.233
x3	-4.359e-15	2.992e-15	-1.457e+00	0.145
x4	-2.761e-15	3.280e-15	-8.420e-01	0.400
x5	1.415e-14	2.437e-15	5.804e+00	6.47e-09 ***
x6	6.083e-15	3.852e-15	1.579e+00	0.114

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	4.823e+33	5.276e+23	9.14e+09	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **-8.717e+05** on 8 Df

Number of iterations: 1 (BFGS) + 1 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 3815 iterations

Return code 0: successful convergence

Log-Likelihood: **136.9978**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	10.9381	0.4934	22.170	< 2e-16 ***
gama1	-2.6896	0.4672	-5.757	8.57e-09 ***
gama2	-6.2774	0.3164	-19.837	< 2e-16 ***
gama3	-7.9849	0.3987	-20.028	< 2e-16 ***
gama4	-3.2299	1.0288	-3.139	0.00169 **
gama5	-12.4650	1.0885	-11.451	< 2e-16 ***
gama6	21.4020	0.2851	75.060	< 2e-16 ***
alpha	81.3443	3.0153	26.977	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 2329 iterations
Return code 0: successful convergence
Log-Likelihood: **162.3959**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	11.3373	0.4306	26.331	< 2e-16 ***
gama1	-0.8839	0.4237	-2.086	0.036980 *
gama2	-4.6642	0.9152	-5.096	3.46e-07 ***
gama3	-6.4744	1.9247	-3.364	0.000769 ***
gama4	2.1528	0.9250	2.327	0.019947 *
gama5	-3.5184	0.6953	-5.061	4.18e-07 ***
gama6	7.5489	1.8756	4.025	5.70e-05 ***
alpha	0.7571	0.2070	3.657	0.000255 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.27. The results of testing the goodness of fit for the residual of the regression models for BCCO 2015.

2015 BCCO	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.5	5.507e-05	8.1122	0.0001287	1.75	2.233e-05
Kumar Reg. Residuals	0.29197	0.04427	2.7764	0.03611	0.50653	0.03732
UGHN Reg. Residuals	0.23245	0.1761	1.6471	0.1453	0.27883	0.1551

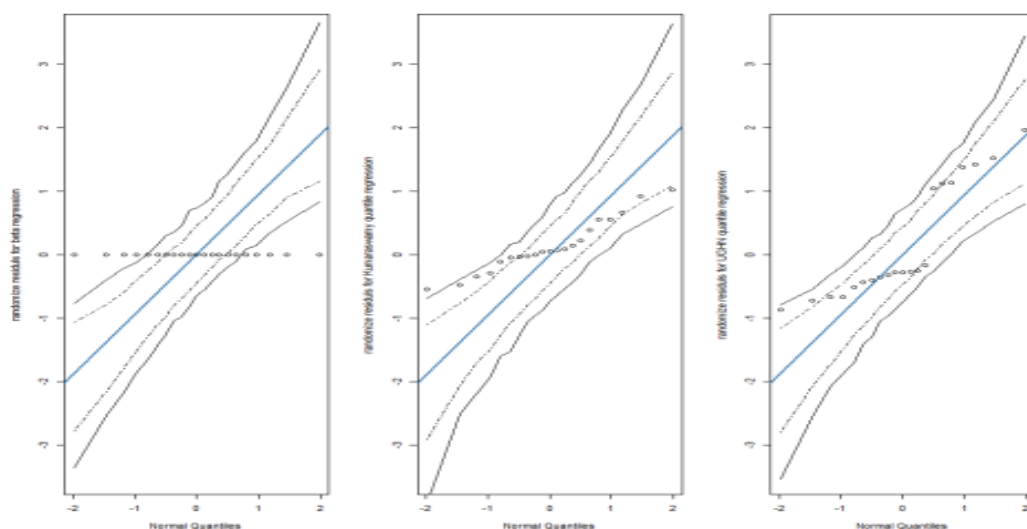


Figure 5.27. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2015.

CCRI/O 2016

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-1.3575	-0.8561	-0.2117	0.9849	2.4277

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	7.4243	0.7112	10.439	< 2e-16	***
x1	-0.1479	1.0908	-0.136	0.89213	
x2	-2.1181	1.6063	-1.319	0.18728	
x3	-4.2475	1.6003	-2.654	0.00795	**
x4	4.2526	1.7232	2.468	0.01359	*
x5	4.9127	1.2285	3.999	6.36e-05	***
x6	-3.6498	2.1183	-1.723	0.08488	.

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)	
(phi)	67.17	27.87	2.41	0.0159	*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **97.08** on 8 Df

Pseudo R-squared: 0.4217

Number of iterations: 128 (BFGS) + 12 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 4627 iterations

Return code 0: successful convergence

Log-Likelihood: **102.0938**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)	
gama0	11.98949	1.24009	9.668	< 2e-16	***
gama1	2.56674	0.10829	23.703	< 2e-16	***
gama2	4.71595	0.44546	10.587	< 2e-16	***
gama3	-5.20793	1.42144	-3.664	0.000248	***
gama4	1.27865	0.51463	2.485	0.012970	*
gama5	4.75782	0.45854	10.376	< 2e-16	***
gama6	-13.13749	0.41159	-31.919	< 2e-16	***
alpha	85.80562	0.02208	3886.420	< 2e-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1363 iterations

Return code 0: successful convergence

Log-Likelihood: **97.58722**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	11.1270	0.2992	37.196	< 2e-16 ***
gama1	-1.4891	0.5548	-2.684	0.00727 **
gama2	-3.3145	1.4090	-2.352	0.01865 *
gama3	-6.7917	0.6685	-10.159	< 2e-16 ***
gama4	10.7022	1.0465	10.227	< 2e-16 ***
gama5	10.8777	0.7016	15.504	< 2e-16 ***
gama6	-8.3520	0.6228	-13.410	< 2e-16 ***
alpha	0.4214	0.0761	5.537	3.07e-08 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.28. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2016.

2016 CCRI/O	One-sample kolmogorov-Smir nov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.083045	0.9961	0.18493	0.9941	0.022338	0.9953
Kumar Reg. Residuals	0.12146	0.8797	0.50764	0.737	0.072933	0.739
UGHN Reg. Residuals	0.11438	0.9176	0.28175	0.9508	0.04038	0.9354

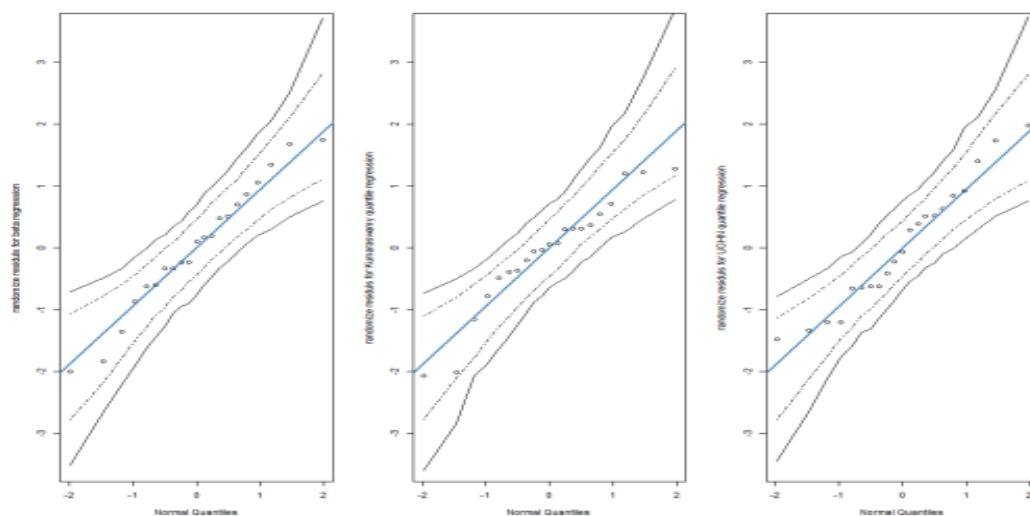


Figure 5.28. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2016.

BCCI 2016

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-5.0599	-1.0989	-0.8712	0.4087	3.8859

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	11.5945	0.5485	21.140	< 2e-16 ***
x1	4.2943	1.0262	4.185	2.86e-05 ***
x2	-5.8717	1.2830	-4.577	4.73e-06 ***
x3	-15.6320	0.9954	-15.704	< 2e-16 ***
x4	14.2969	1.7472	8.183	2.78e-16 ***
x5	2.8620	1.3417	2.133	0.0329 *
x6	2.1259	1.8534	1.147	0.2514

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	10170	3545	2.869	0.00412 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **151.2** on 8 Df

Pseudo R-squared: 0.5411

Number of iterations: 5000 (BFGS) + 26 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 2275 iterations

Return code 0: successful convergence

Log-Likelihood: **129.743**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	4.9033	1.5296	3.206	0.00135 **
gama1	1.2173	0.4288	2.839	0.00453 **
gama2	11.4178	1.1205	10.190	< 2e-16 ***
gama3	15.1443	1.7028	8.894	< 2e-16 ***
gama4	-11.2867	0.5658	-19.949	< 2e-16 ***
gama5	-2.1208	0.1874	-11.316	< 2e-16 ***
gama6	-11.4907	2.0209	-5.686	1.3e-08 ***
alpha	47.2836	1.4907	31.719	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1191 iterations

Return code 0: successful convergence

Log-Likelihood: **145.5361**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	6.97159	0.73053	9.543	< 2e-16 ***
gama1	1.17070	0.42271	2.770	0.00561 **
gama2	0.97676	0.42227	2.313	0.02072 *
gama3	5.78466	0.69869	8.279	< 2e-16 ***
gama4	-4.62157	0.32483	-14.228	< 2e-16 ***
gama5	-6.66883	0.30645	-21.762	< 2e-16 ***
gama6	0.93922	0.39440	2.381	0.01725 *
alpha	0.44753	0.08383	5.339	9.36e-08 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.29 The results of testing the goodness of fit for the residual of the regression models For BCCI 2016.

2016 BCCI	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.24547	0.1339	2.8029	0.035	0.38136	0.08015
Kumar Reg. Residuals	0.36952	0.004428	3.4063	0.01744	0.69077	0.01258
UGHN Reg. Residuals	0.21341	0.2556	1.1819	0.274	0.22568	0.2234

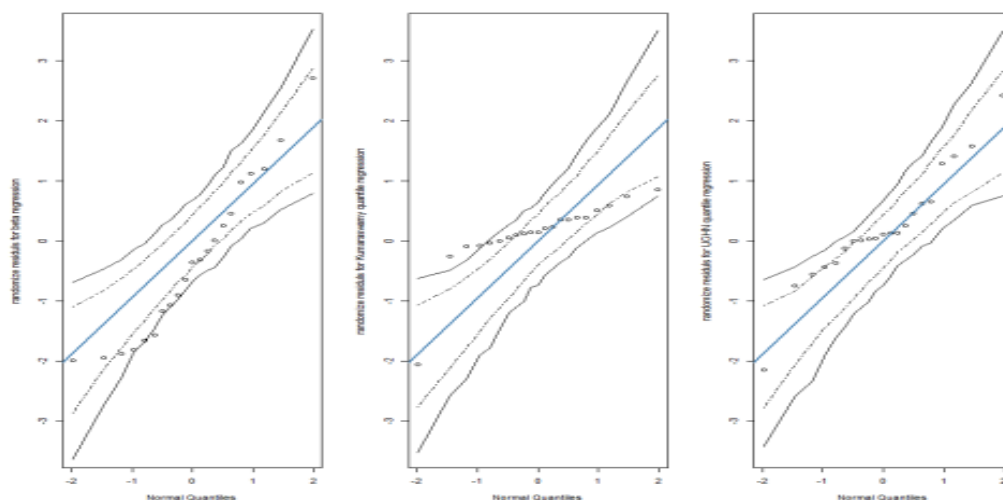


Figure 5.29. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2016.

BCCO 2016

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-5.0561	-1.0997	-0.8692	0.4167	3.8762

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	11.5768	0.5471	21.162	< 2e-16 ***
x1	4.2742	1.0245	4.172	3.02e-05 ***
x2	-5.8328	1.2805	-4.555	5.24e-06 ***
x3	-15.5388	0.9932	-15.646	< 2e-16 ***
x4	14.2030	1.7443	8.142	3.88e-16 ***
x5	2.8425	1.3393	2.122	0.0338 *
x6	2.1137	1.8496	1.143	0.2531

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	10247	3568	2.872	0.00408 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **151.4** on 8 Df

Pseudo R-squared: 0.5413

Number of iterations: 5000 (BFGS) + 28 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 3845 iterations

Return code 0: successful convergence

Log-Likelihood: **135.101**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	14.8897	0.7192	20.703	< 2e-16 ***
gama1	-3.7945	0.6169	-6.151	7.7e-10 ***
gama2	-16.1168	1.0387	-15.517	< 2e-16 ***
gama3	-22.3722	0.5338	-41.908	< 2e-16 ***
gama4	16.9179	0.5855	28.896	< 2e-16 ***
gama5	1.8442	0.2733	6.748	1.5e-11 ***
gama6	17.5366	0.1036	169.217	< 2e-16 ***
alpha	111.5268	2.2521	49.522	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1601 iterations
Return code 0: successful convergence
Log-Likelihood: **149.9478**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	11.6770	0.4801	24.320	< 2e-16 ***
gama1	-6.5698	0.3819	-17.204	< 2e-16 ***
gama2	-7.5940	0.3861	-19.667	< 2e-16 ***
gama3	-3.9455	0.2620	-15.059	< 2e-16 ***
gama4	-1.0953	0.1310	-8.361	< 2e-16 ***
gama5	-3.0097	0.1919	-15.681	< 2e-16 ***
gama6	14.1125	0.1901	74.249	< 2e-16 ***
alpha	0.6585	0.1777	3.707	0.00021 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.30. The results of testing the goodness of fit for the residual of the regression models for BCCO 2016.

2016 BCCO	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.24429	0.1373	2.7693	0.03641	0.37793	0.08189
Kumar Reg. Residuals	0.31098	0.02658	2.5035	0.04991	0.43932	0.05604
UGHN Reg. Residuals	0.15486	0.6397	0.58121	0.6639	0.089628	0.6429

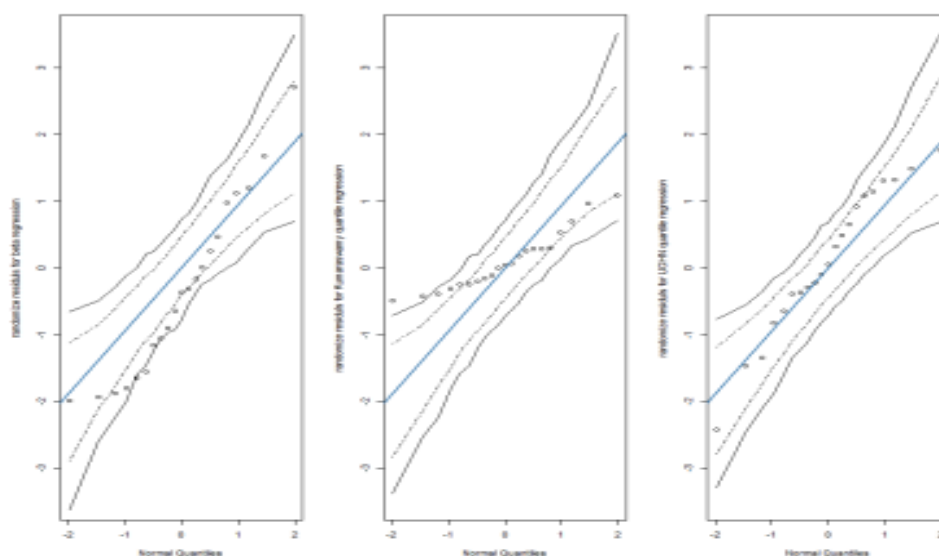


Figure 5.30. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2016.

CCRI/O 2017

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-1.2705	-0.5481	0.0917	0.5121	2.4602

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.82488	0.76978	6.268	3.66e-10 ***
x1	0.04251	1.40236	0.030	0.9758
x2	-1.18803	1.80481	-0.658	0.5104
x3	-2.72654	1.79599	-1.518	0.1290
x4	3.32572	1.90814	1.743	0.0813 .
x5	3.79499	1.58316	2.397	0.0165 *
x6	-3.29444	2.32465	-1.417	0.1564

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	8.655	3.778	2.291	0.022 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **84.58** on 8 Df

Pseudo R-squared: 0.4239

Number of iterations: 45 (BFGS) + 9 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1991 iterations

Return code 0: successful convergence

Log-Likelihood: **87.57509**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	10.0440	1.2082	8.313	< 2e-16 ***
gama1	6.3821	1.1952	5.340	9.31e-08 ***
gama2	-1.1096	0.3134	-3.541	0.000398 ***
gama3	-7.6244	0.8235	-9.259	< 2e-16 ***
gama4	4.7168	1.3604	3.467	0.000526 ***
gama5	5.1543	2.4829	2.076	0.037898 *
gama6	-11.3726	2.0782	-5.472	4.44e-08 ***
alpha	14.9454	1.0779	13.866	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1877 iterations

Return code 0: successful convergence

Log-Likelihood: **89.08883**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	10.62960	0.33275	31.944	< 2e-16 ***
gama1	3.43845	0.52761	6.517	7.17e-11 ***
gama2	-2.00523	0.38646	-5.189	2.12e-07 ***
gama3	-7.35478	0.39420	-18.657	< 2e-16 ***
gama4	2.40263	1.01912	2.358	0.018395 *
gama5	2.99961	0.86022	3.487	0.000488 ***
gama6	-4.87366	1.84239	-2.645	0.008162 **
alpha	0.35490	0.04847	7.322	2.45e-13 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.31. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2017.

2017 CCRI/O	One-sample Kolmogorov-Smir nov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.20941	0.2753	0.9262	0.3972	0.1905	0.288
Kumar Reg. Residuals	0.24385	0.1386	1.5345	0.1686	0.28762	0.1463
UGHN Reg. Residuals	0.093236	0.985	0.2289	0.9804	0.032252	0.9712

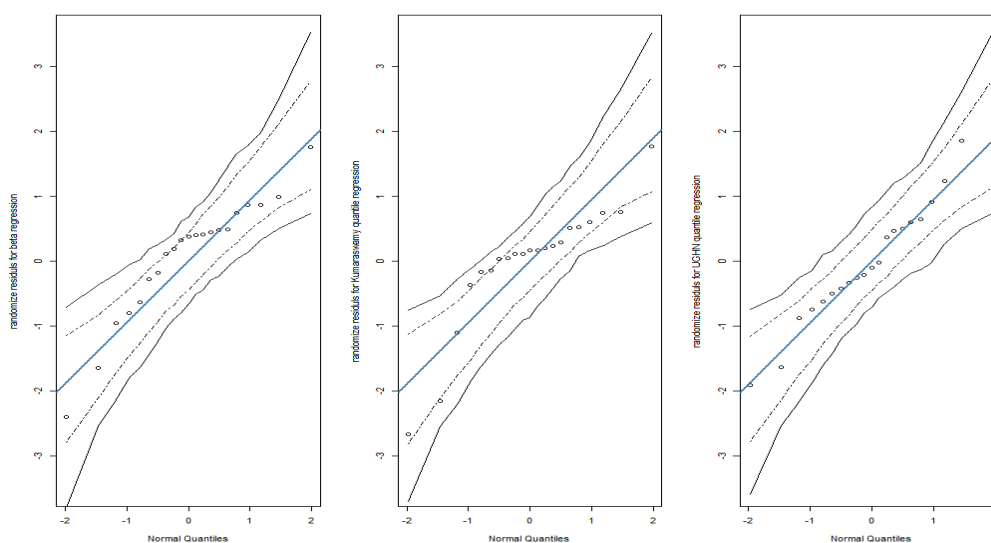


Figure 5.31. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2017.

BCCI 2017

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-1.7500	-0.1598	0.0669	0.1765	1.3081

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.3024	0.8003	5.376	7.62e-08 ***
x1	1.7353	1.5517	1.118	0.263
x2	0.2783	1.8989	0.147	0.883
x3	-1.5853	1.8909	-0.838	0.402
x4	1.6934	1.9990	0.847	0.397
x5	0.9081	1.7189	0.528	0.597
x6	-2.0479	2.4628	-0.832	0.406

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	12.608	6.638	1.899	0.0575 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **118.7** on 8 Df

Pseudo R-squared: 0.4233

Number of iterations: 1119 (BFGS) + 11 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 2147 iterations

Return code 0: successful convergence

Log-Likelihood: **123.4651**

Eight free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	1.093e+01	2.804e-03	3.898e+03	<2e-16 ***
gama1	1.804e+01	1.635e-07	1.104e+08	<2e-16 ***
gama2	-5.445e+00	1.423e-01	-3.825e+01	<2e-16 ***
gama3	-2.041e+01	1.538e-01	-1.327e+02	<2e-16 ***
gama4	5.316e+01	2.804e-03	1.896e+04	<2e-16 ***
gama5	1.669e+01	2.970e-07	5.618e+07	<2e-16 ***
gama6	-3.577e+01	1.550e-02	-2.308e+03	<2e-16 ***
alpha	5.501e+01	1.146e-02	4.798e+03	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 2285 iterations
Return code 0: successful convergence
Log-Likelihood: **142.5173**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.87170	0.35676	24.868	< 2e-16 ***
gama1	1.45661	0.14811	9.835	< 2e-16 ***
gama2	-2.26941	0.39041	-5.813	6.14e-09 ***
gama3	-5.49310	0.07978	-68.851	< 2e-16 ***
gama4	5.20331	0.29073	17.897	< 2e-16 ***
gama5	-1.77409	0.47868	-3.706	0.00021 ***
gama6	3.45578	0.38941	8.874	< 2e-16 ***
alpha	0.70164	0.15002	4.677	2.91e-06 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.32. The results of testing the goodness of fit for the residual of the regression models for BCCI 2017.

2017 BCCI	One-sample Kolmogorov-Smir Nov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.37831	0.003286	3.1561	0.02322	0.69365	0.01237
Kumar Reg. Residuals	0.19369	0.3628	1.0829	0.3158	0.19213	0.2845
UGHN Reg. Residuals	0.23848	0.1554	1.3639	0.2125	0.25839	0.1781

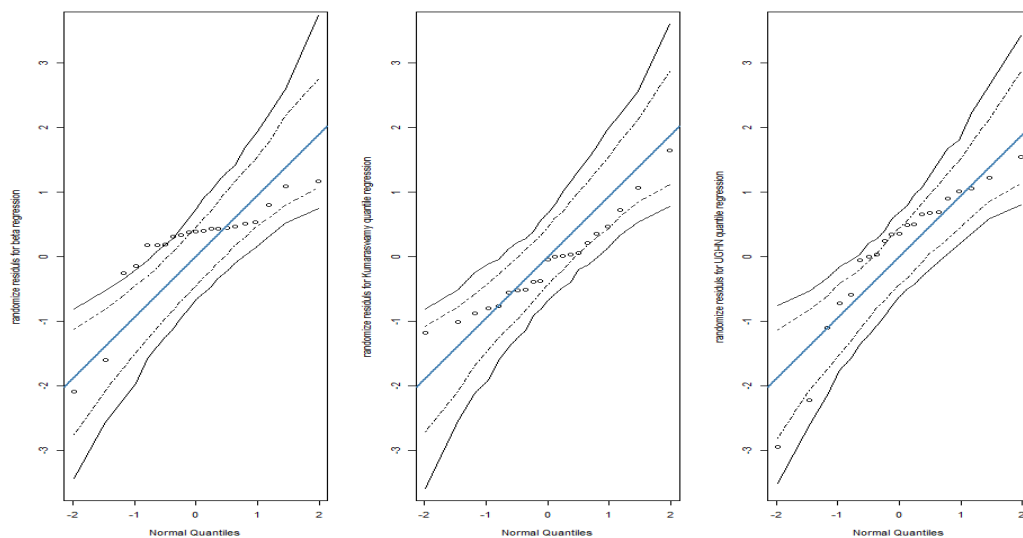


Figure 5.32. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2017.

BCCO 2017

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-1.7948	-0.1788	0.0892	0.2097	1.3006

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.3697	0.8010	5.455	4.89e-08 ***
x1	1.7688	1.5504	1.141	0.254
x2	0.1776	1.8967	0.094	0.925
x3	-1.8222	1.8850	-0.967	0.334
x4	1.8313	1.9969	0.917	0.359
x5	0.8850	1.7183	0.515	0.607
x6	-1.9016	2.4600	-0.773	0.440

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	13.08	6.87	1.904	0.057 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **118.8** on 8 Df

Pseudo R-squared: 0.4195

Number of iterations: 728 (BFGS) + 14 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1587 iterations

Return code 0: successful convergence

Log-Likelihood: **120.6144**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.1285	0.8532	9.527	< 2e-16 ***
gama1	5.6189	1.1231	5.003	5.65e-07 ***
gama2	-3.8205	1.0668	-3.581	0.000342 ***
gama3	-12.8387	0.4193	-30.619	< 2e-16 ***
gama4	11.6216	0.1246	93.265	< 2e-16 ***
gama5	12.3220	0.9184	13.416	< 2e-16 ***
gama6	-2.2815	0.4183	-5.455	4.91e-08 ***
alpha	23.9426	1.1008	21.751	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of (UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1629 iterations
Return code 0: successful convergence
Log-Likelihood: **127.0348**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	5.76544	0.37620	15.325	< 2e-16 ***
gama1	-5.52790	0.09161	-60.339	< 2e-16 ***
gama2	9.86926	0.14608	67.559	< 2e-16 ***
gama3	17.93347	0.38939	46.056	< 2e-16 ***
gama4	-4.23932	0.50212	-8.443	< 2e-16 ***
gama5	4.53453	0.22310	20.325	< 2e-16 ***
gama6	-15.58035	0.50150	-31.068	< 2e-16 ***
alpha	0.28969	0.04149	6.982	2.92e-12 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.33. The results of testing the goodness of fit for the residual of the regression models for BCCO 2017.

2017 BCCO	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.371	0.004213	3.038	0.02661	0.66387	0.01472
Kumar Reg. Residuals	0.3033	0.03279	2.8441	0.03335	0.57151	0.02535
UGHN Reg. Residuals	0.21218	0.2616	1.2039	0.2656	0.22613	0.2227

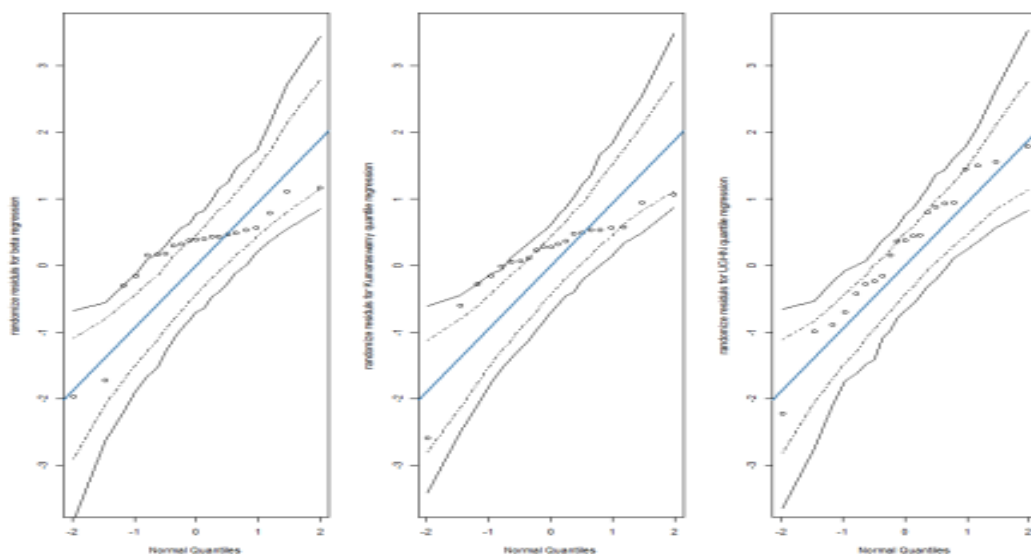


Figure 5.33. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2017.

CCRI/O 2018

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-1.6946	-0.6089	0.0593	0.6805	1.7903

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	3.70636	0.82355	4.500	6.78e-06	***
x1	-0.05965	1.58086	-0.038	0.970	
x2	-0.43170	1.96044	-0.220	0.826	
x3	-1.49472	2.55461	-0.585	0.558	
x4	0.33522	2.52715	0.133	0.894	
x5	0.72862	1.74150	0.418	0.676	
x6	-0.32750	2.60391	-0.126	0.900	

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)	
(phi)	3.826	1.725	2.218	0.0266	*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **79.93** on 8 Df

Pseudo R-squared: 0.155

Number of iterations: 52 (BFGS) + 9 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1301 iterations

Return code 0: successful convergence

Log-Likelihood: **82.75924**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)	
gama0	11.2841	0.8501	13.274	< 2e-16	***
gama1	-2.8844	0.8189	-3.522	0.000428	***
gama2	3.8126	0.9135	4.173	3.00e-05	***
gama3	-1.3810	0.2782	-4.964	6.90e-07	***
gama4	-5.1246	0.6684	-7.667	1.76e-14	***
gama5	3.3023	1.1406	2.895	0.003789	**
gama6	-6.9956	1.3930	-5.022	5.11e-07	***
alpha	8.0904	0.8406	9.624	< 2e-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1551 iterations
Return code 0: successful convergence
Log-Likelihood: **81.10779**
8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)	
gama0	4.03634	0.92180	4.379	1.19e-05	***
gama1	5.42502	1.49648	3.625	0.000289	***
gama2	5.92240	1.19328	4.963	6.94e-07	***
gama3	-4.66152	0.73950	-6.304	2.91e-10	***
gama4	7.69752	1.37201	5.610	2.02e-08	***
gama5	-2.28987	0.73037	-3.135	0.001717	**
gama6	-3.11239	0.79345	-3.923	8.76e-05	***
alpha	0.23616	0.06272	3.765	0.000166	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.34. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2018.

2018 CCRI/O	One-sample Kolmogorov-Smir nov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.18909	0.3915	0.81011	0.4722	0.15871	0.3662
Kumar Reg. Residuals	0.20357	0.3059	0.89453	0.4163	0.14429	0.4101
UGHN Reg. Residuals	0.21575	0.2446	0.71629	0.5435	0.12639	0.4735

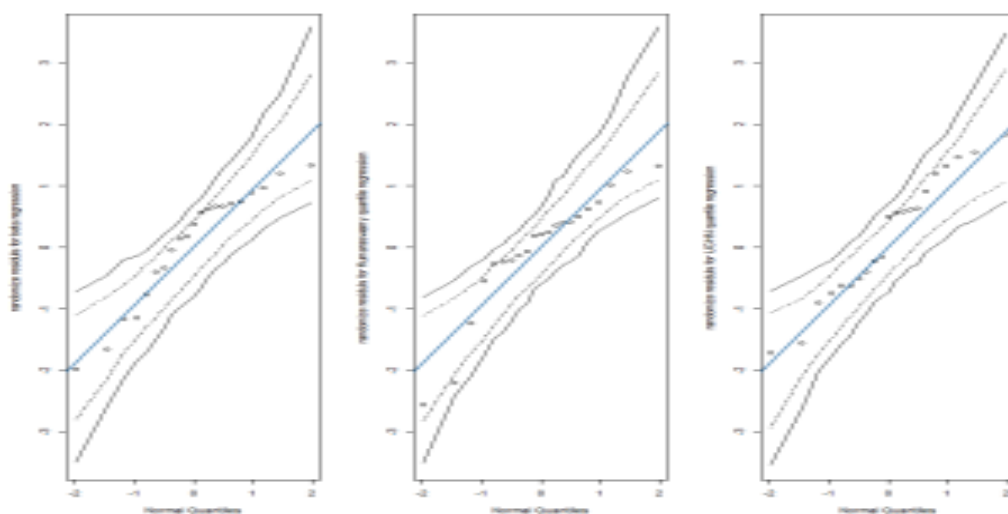


Figure 5.34. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2018.

BCCI 2018

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-1.3247	-0.2617	0.0575	0.4563	1.0514

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.6190	0.7698	6.000	1.97e-09 ***
x1	1.2386	1.5154	0.817	0.414
x2	1.5486	1.8827	0.823	0.411
x3	1.0942	2.4396	0.449	0.654
x4	-3.1215	2.3542	-1.326	0.185
x5	-1.5574	1.6557	-0.941	0.347
x6	-0.4229	2.4853	-0.170	0.865

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	28.57	14.38	1.986	0.047 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **115.1** on 8 Df

Pseudo R-squared: 0.1721

Number of iterations: 263 (BFGS) + 9 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 2919 iterations

Return code 0: successful convergence

Log-Likelihood: **115.5461**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	4.6942	0.9904	4.740	2.14e-06 ***
gama1	4.9637	1.5120	3.283	0.00103 **
gama2	14.7809	0.9384	15.752	< 2e-16 ***
gama3	10.6021	0.5111	20.744	< 2e-16 ***
gama4	-16.9552	1.3790	-12.295	< 2e-16 ***
gama5	-6.0156	2.1358	-2.817	0.00485 **
gama6	-8.4261	0.4988	-16.893	< 2e-16 ***
alpha	36.9672	6.1602	6.001	1.96e-09 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1819 iterations
Return code 0: successful convergence
Log-Likelihood: **130.0364**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	9.5093	0.5336	17.823	< 2e-16 ***
gama1	-2.4578	0.1266	-19.421	< 2e-16 ***
gama2	-4.1797	0.5896	-7.089	1.35e-12 ***
gama3	-4.6750	0.1083	-43.155	< 2e-16 ***
gama4	9.4427	0.8463	11.157	< 2e-16 ***
gama5	3.3645	0.6468	5.202	1.97e-07 ***
gama6	1.2329	0.3558	3.465	0.00053 ***
alpha	0.5814	0.1317	4.414	1.01e-05 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.35. The results of testing the goodness of fit for the residual of the regression models for BCCI 2018.

2018 BCCI	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.3481	0.008873	2.8917	0.03155	0.5839	0.02356
Kumar Reg. Residuals	0.2872	0.05006	2.6276	0.04305	0.50575	0.0375
UGHN Reg. Residuals	0.2887	0.04817	1.8874	0.1066	0.3331	0.1088

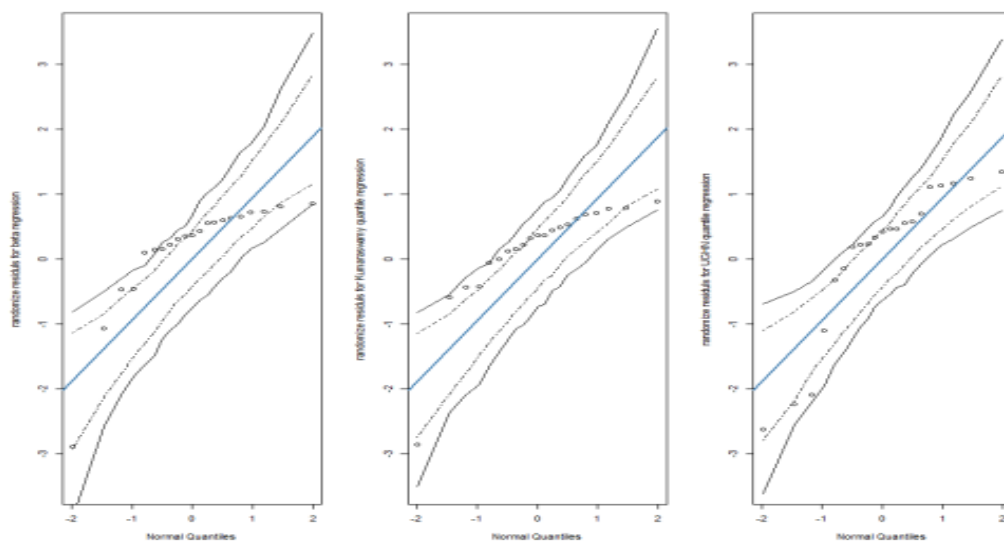


Figure 5.35. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2018.

BCCO 2018

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

	Min	1Q	Median	3Q	Max
	-1.3466	-0.1616	0.0997	0.3507	0.8994

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.0303	0.7977	5.052	4.37e-07 ***
x1	0.8072	1.5370	0.525	0.599
x2	1.1257	1.9065	0.590	0.555
x3	0.6672	2.4774	0.269	0.788
x4	-1.8552	2.4417	-0.760	0.447
x5	-0.9953	1.6916	-0.588	0.556
x6	-0.3480	2.5259	-0.138	0.890

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	13.103	6.886	1.903	0.0571 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **111.9** on 8 Df

Pseudo R-squared: 0.1277

Number of iterations: 117 (BFGS) + 6 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 3797 iterations

Return code 0: successful convergence

Log-Likelihood: **111.6968**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	5.1588	1.9214	2.685	0.007255 **
gama1	4.1323	1.5914	2.597	0.009412 **
gama2	9.2478	2.5658	3.604	0.000313 ***
gama3	5.7934	2.6853	2.157	0.030972 *
gama4	-11.4826	0.9148	-12.552	< 2e-16 ***
gama5	-5.5118	2.2221	-2.480	0.013122 *
gama6	-4.0982	1.1648	-3.518	0.000434 ***
alpha	13.8320	6.0330	2.293	0.021865 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1353 iterations

Return code 0: successful convergence

Log-Likelihood: **121.1449**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	5.75021	1.99199	2.887	0.00389 **
gama1	12.18507	1.71509	7.105	1.21e-12 ***
gama2	1.18839	0.01754	67.734	< 2e-16 ***
gama3	-5.02602	2.20548	-2.279	0.02267 *
gama4	-9.57796	2.23022	-4.295	1.75e-05 ***
gama5	-16.13730	0.07578	-212.939	< 2e-16 ***
gama6	11.21195	2.01631	5.561	2.69e-08 ***
alpha	0.31810	0.08137	3.909	9.26e-05 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.36. The results of testing the goodness of fit for the residual of the regression models for BCCO 2018.

2018 BCCO	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.37832	0.003284	3.9598	0.009332	0.80765	0.006373
Kumar Reg. Residuals	0.33784	0.01218	3.8024	0.01114	0.77098	0.007885
UGHN Reg. Residuals	0.18375	0.4264	0.78325	0.4916	0.14334	0.4132

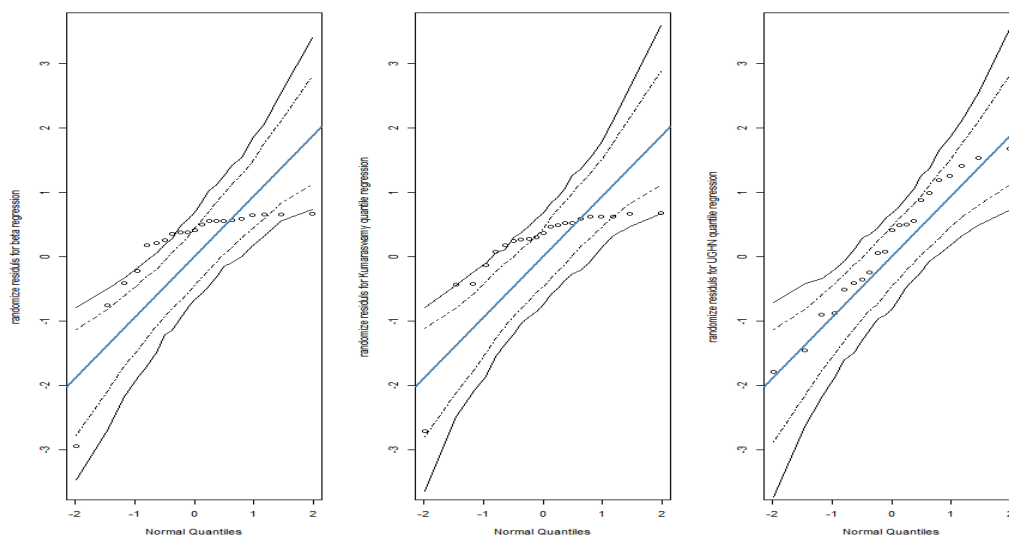


Figure 5.36. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2018.

CCRI/O 2019

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
-1.3094	-0.6212	-0.0360	0.3878	1.6984

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	3.7112	0.6559	5.658	1.53e-08	***
x1	3.7246	1.3262	2.808	0.004979	**
x2	3.7860	1.8598	2.036	0.041775	*
x3	2.2503	2.3959	0.939	0.347600	
x4	-2.8193	2.5428	-1.109	0.267546	
x5	0.6661	1.8021	0.370	0.711667	
x6	-7.9295	2.3804	-3.331	0.000865	***

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)	
(phi)	13.033	5.654	2.305	0.0212	*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **92.78** on 8 Df

Pseudo R-squared: 0.6574

Number of iterations: 131 (BFGS) + 11 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1751 iterations

Return code 0: successful convergence

Log-Likelihood: **97.80545**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)	
gama0	9.28273	0.03699	250.93	<2e-16	***
gama1	6.12511	0.27277	22.45	<2e-16	***
gama2	22.88138	0.19807	115.52	<2e-16	***
gama3	10.17563	0.10975	92.72	<2e-16	***
gama4	-15.82364	0.12122	-130.54	<2e-16	***
gama5	0.74956	0.01978	37.89	<2e-16	***
gama6	-26.90159	0.12830	-209.67	<2e-16	***
alpha	23.92399	0.10599	225.72	<2e-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 2091 iterations

Return code 0: successful convergence

Log-Likelihood: **108.1783**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	6.2563	0.5748	10.885	< 2e-16 ***
gama1	10.7702	2.2566	4.773	1.82e-06 ***
gama2	10.7876	1.5631	6.901	5.15e-12 ***
gama3	5.9969	1.6160	3.711	0.000206 ***
gama4	-4.7585	0.8568	-5.554	2.79e-08 ***
gama5	1.9100	0.1255	15.217	< 2e-16 ***
gama6	-22.3510	0.5326	-41.963	< 2e-16 ***
alpha	0.7120	0.2601	2.738	0.006186 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.37. The results of testing the goodness of fit for the residual of the regression models for CCRI/O 2019.

2019 CCRI/O	One-sample Kolmogorov-Smirnov test		One-sample Anderson-Darling test		One-sample Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.18307	0.4309	0.88505	0.4222	0.16002	0.3626
Kumar Reg. Residuals	0.18834	0.3962	1.6015	0.1543	0.26473	0.1706
UGHN Reg. Residuals	0.15701	0.623	0.59897	0.6469	0.1021	0.5789

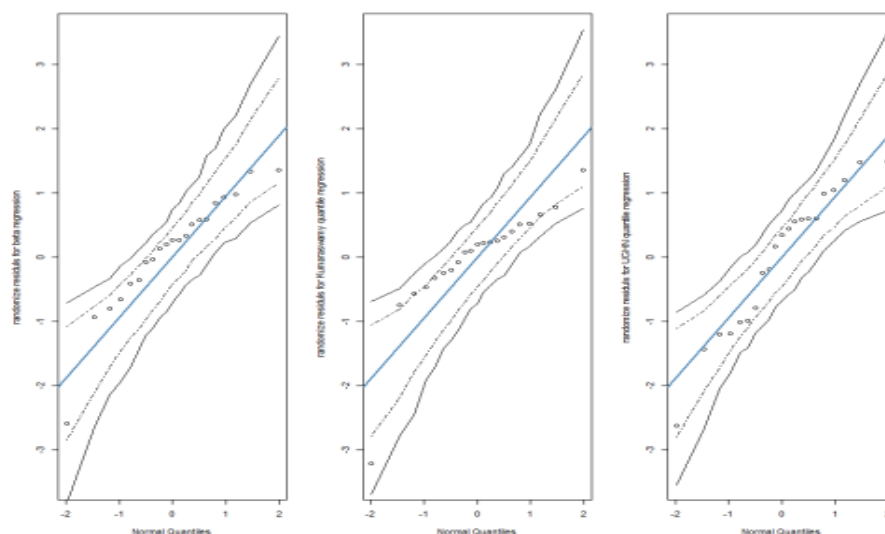


Figure 5.37. The regression of (Beta, Kumaraswamy, (UGHN)) for CCRI/O 2019.

BCCI 2019

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
-1.8329	-0.4349	-0.0853	0.5070	1.9455

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	3.4993	0.7257	4.822	1.42e-06 ***
x1	2.4016	1.4569	1.648	0.0993 .
x2	3.5770	1.9991	1.789	0.0736 .
x3	3.3794	2.5677	1.316	0.1881
x4	-3.1330	2.8379	-1.104	0.2696
x5	-0.7769	2.0219	-0.384	0.7008
x6	-4.9224	2.7780	-1.772	0.0764 .

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	13.22	6.67	1.982	0.0475 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **114.6** on 8 Df

Pseudo R-squared: 0.5453

Number of iterations: 3107 (BFGS) + 6 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1525 iterations

Return code 0: successful convergence

Log-Likelihood: **120.5468**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	2.83195	0.08712	32.51	<2e-16 ***
gama1	13.13019	0.35650	36.83	<2e-16 ***
gama2	38.39535	0.23651	162.34	<2e-16 ***
gama3	39.32146	0.65185	60.32	<2e-16 ***
gama4	-38.69313	0.48998	-78.97	<2e-16 ***
gama5	-14.13057	0.20640	-68.46	<2e-16 ***
gama6	-36.29263	0.01204	-3015.44	<2e-16 ***
alpha	31.12613	0.01687	1844.90	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation
Nelder-Mead maximization, 1501 iterations
Return code 0: successful convergence
Log-Likelihood: **134.7427**
8 free parameters
Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	8.5032	0.4703	18.081	< 2e-16 ***
gama1	3.4231	0.7682	4.456	8.35e-06 ***
gama2	1.3861	0.4732	2.929	0.003398 **
gama3	1.3195	0.2987	4.417	1.00e-05 ***
gama4	-9.7143	0.4711	-20.621	< 2e-16 ***
gama5	-6.3820	0.7465	-8.549	< 2e-16 ***
gama6	4.4351	0.4631	9.576	< 2e-16 ***
alpha	0.6065	0.1720	3.527	0.000421 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.38. The results of testing the goodness of fit for the residual of the regression models for BCCI 2019.

2019 BCCI	One-sample Kolmogorov-Smir nov test		Anderson-Darling test		Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.33938	0.01162	2.0349	0.08847	0.43166	0.05872
Kumar Reg. Residuals	0.24627	0.1316	1.6389	0.1469	0.25605	0.1809
UGHN Reg. Residuals	0.14504	0.716	0.65964	0.5915	0.097192	0.6033

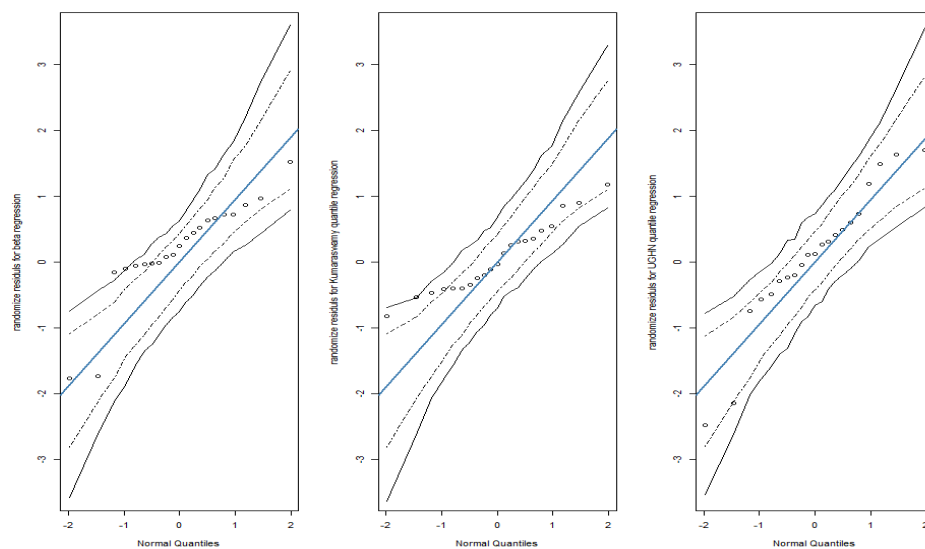


Figure 5.38. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCI 2019.

BCCO 2019

summary(gy) ## The results of Beta regression analysis ##

Call:

betareg(formula = y ~ x1 + x2 + x3 + x4 + x5 + x6, link = "logit")

Standardized weighted residuals 2:

Min	1Q	Median	3Q	Max
-1.7026	-0.4160	-0.0577	0.4805	1.8877

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	3.7629	0.7198	5.228	1.72e-07 ***
x1	2.2987	1.4489	1.587	0.1126
x2	3.5347	1.9898	1.776	0.0757 .
x3	3.3034	2.5559	1.292	0.1962
x4	-2.9816	2.8238	-1.056	0.2910
x5	-0.7033	2.0122	-0.350	0.7267
x6	-4.8337	2.7588	-1.752	0.0798 .

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(> z)
(phi)	17.887	9.015	1.984	0.0473 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Type of estimator: ML (maximum likelihood)

Log-likelihood: **116.5** on 8 Df

Pseudo R-squared: 0.5357

Number of iterations: 3708 (BFGS) + 12 (Fisher scoring)

The results of Kumaraswamy regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 4375 iterations

Return code 0: successful convergence

Log-Likelihood: **124.7194**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	3.46929	0.17564	19.75	<2e-16 ***
gama1	11.12403	0.50018	22.24	<2e-16 ***
gama2	44.97287	0.17563	256.06	<2e-16 ***
gama3	44.18115	0.28833	153.23	<2e-16 ***
gama4	-41.59408	0.41650	-99.86	<2e-16 ***
gama5	-13.49441	0.09115	-148.04	<2e-16 ***
gama6	-41.75986	0.52697	-79.25	<2e-16 ***
alpha	78.64803	0.74766	105.19	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The results of(UGHN) regression analysis

Maximum Likelihood estimation

Nelder-Mead maximization, 1563 iterations

Return code 0: successful convergence

Log-Likelihood: **127.689**

8 free parameters

Estimates:

	Estimate	Std. error	t value	Pr(> t)
gama0	5.29836	0.05747	92.194	< 2e-16 ***
gama1	10.60895	0.48658	21.803	< 2e-16 ***
gama2	8.15565	0.37618	21.680	< 2e-16 ***
gama3	11.25970	0.49714	22.649	< 2e-16 ***
gama4	-20.97724	0.08323	-252.044	< 2e-16 ***
gama5	-14.05573	0.54198	-25.934	< 2e-16 ***
gama6	-1.19755	0.33125	-3.615	3e-04 ***
alpha	0.36601	0.04713	7.767	8.07e-15 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5.39. The results of testing the goodness of fit for the residual of the regression models for BCCO 2019.

2019 BCCO	One-sample Kolmogorov-Smir nov test		Anderson-Darling test		Cramer-von Mises test	
	D	P-value	An	P-value	omega2	P-value
Beta Reg. Residuals	0.35331	0.007524	2.1853	0.07342	0.46994	0.04652
Kumar Reg. Residuals	0.20589	0.2935	1.3129	0.228	0.20263	0.2635
UGHN Reg. Residuals	0.15789	0.6162	0.65717	0.5937	0.096291	0.6079

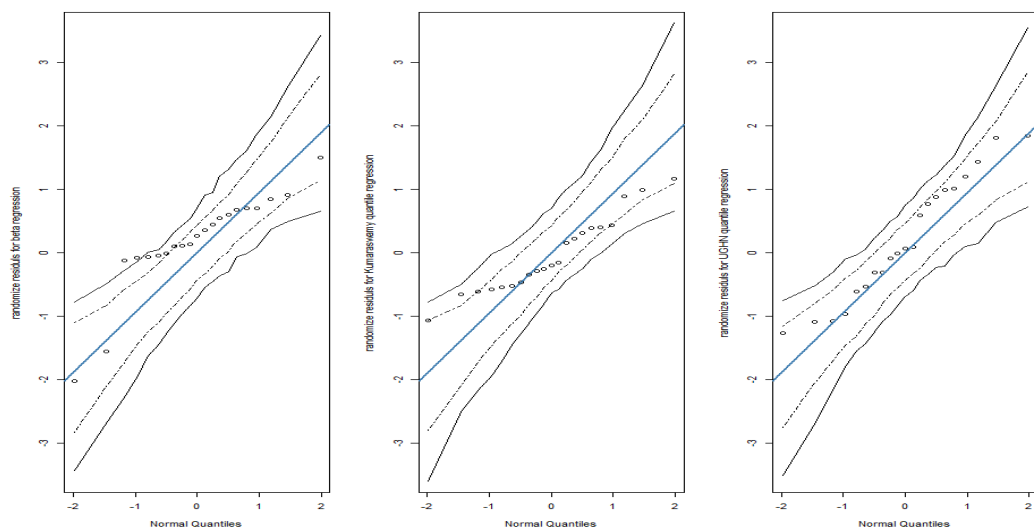


Figure 5.39. The regression of (Beta, Kumaraswamy, (UGHN)) for BCCO 2019.

5.3. Conclusions Of The Second Stage Applying Regression Analysis

To consolidate the results that we obtained through the operations we carried out in the second stage. We made a table to collect the Maximum likelihood (ML) values that we got when we computed the regression analysis for the three models, which were applied to the four data envelopment analysis models, table 5.40 and charts 5.1, 5.2, and 5.3 illustrate this. In addition, we generated Table 5.41 to show the number of successes of each regression model as best among the other regressions, according to the quality of the concordance tests performed on the three regression models (Beta, Kumaraswamy, UGHN). The percentages of these successes were also calculated in Tables 5.42, 5.43, and charts 5.4, 5.5, showing the frequencies and percentage of the goodness of fit of these regressions.

In the first stage, the models (CCR-I, CCR-O, BCC-I, BCC-O) were used for 13 years, so we have 52 efficiency tables, and because the efficiency values of CCR-I and CCR-O were the same, so we combined them and considered them as one value and collected in one model in the regression analysis equations, we called it CCR-I/O model. Thus, we have 39 regression models instead of 52, with three models per year (CCR-I/O, BCC-I, BCC-O). All 39 models passed three tests for goodness of fit, resulting in 117 test results and 117 ML values. These results will be used as a basis for the analysis.

We had previously presented the results obtained in the second stage of the research, which is the stage of calculating the (ML) for estimating the parameters of regression equations for distributions (Beta, Kumaraswamy, UGHN) as well as measuring the agreement and acceptability of the regression equations that we obtained by testing them with three tests for goodness of fit. All operations and results obtained in the second stage were done through the use of the R program, and then the results were collected and tabulated as in tables 5.40, 5.41, 5.42, 5.43, and charts 5.1, 5.2, 5.3, 5.4, and 5.5. From an overview of these results and the diagrams, we can analyze the outcomes of regression that we had obtained from two angles :

5.3.1. The first angle: analyzes the ML values of the three regression equations for some models

1. The Beta distribution fails to find the value of ML several times, which are (2013, in the CCR-I / O model), (2010, 2011, 2012, 2013, in the BCC-I model), (2010, 2011, 2012, in the BCC-O model).
2. In 2015, the ML was a significant negative value (ML = (Log-likelihood: -8.717e+05) in the BCC-I model and the beta regression equation was far from illogical. Also, in the same year in the BCC-O model, the ML had a value of Large negative ML = Log-likelihood: -8.717e+05, and here too, the beta regression equation was far from illogical.
3. Contrary to beta regression, quantile regression (Kumaraswamy & UGHN) did not fail in any of the years to find the regression equation for the (CCR-I/O, BCC-I, BCC-O) models, and none of its ML values were negative.
4. The Unit Generalized Half Normal (UGHN) Distribution achieved the highest values for ML in the models (CCR-I/O, BCC-I, BCC-O) for all years except 2016, where the ML value was the highest in the beta distribution for the (BCC-O, BCC-I) models. Also, the ML value was higher than the other in the Kumaraswamy distribution for the CCR-I/O model in 2016 and 2018.
5. Since the UGHN Distribution achieved the highest values of ML for 13 years in models (CCR-I/O, BCC-I, BCC-O), this distribution has the highest sum of ML values in each model among the rest of the other distributions. For example, in table 57, we can notice the percentages of recurrence of the highest values for ML in (CCR-I/O, BCC-I, BCC-O) models, and the percentages of ML values being the highest in (UGHN) Distribution are 84.6% in the CCR-I/O model, 92.3% in BCC-I and BCC-O models, respectively, and the total percentage of 89.74%.

Table 5.40. ML values of the regression models (Beta, Kumaraswamy, UGHN) constructed for the DEA equations (CCR-I/O, BCC-I, BCC-O), 2007-2019.

2007 -2019	CCR-I / CCR-O			BCC-I			BCC-O			Total
Years	MAX. Beta Reg.	MAX. Kumara Reg.	MAX. UGHN Reg.	MAX. Beta Reg.	MAX. Kumara Reg.	MAX. UGHN Reg.	MAX. Beta Reg.	MAX. Kumara Reg.	MAX. UGHN Reg.	The Sum
2007	97.33	100.9787	106.3946	120.8	121.2772	128.47	119.9	125.9173	138.4124	1059.4802
2008	94.91	98.70832	101.3853	120.9	121.1398	140.1903	119.5	121.1523	142.3466	1060.23262
2009	97.77	99.80076	108.766	121.8	129.2727	140.3018	121.7	131.1575	136.2072	1086.77596
2010	94.04	94.88526	102.6122		120.616	144.2266		120.4846	130.2922	807.15686
2011	116.3	120.4813	131.0272		131.3348	141.8764		130.5822	153.3382	924.9401
2012	114.4	114.4577	136.1839		121.1465	147.3611		120.7059	132.7464	887.0015
2013		107.2154	117.7409		117.1161	129.6094	114.8	115.4359	119.7175	821.6352
2014	114.3	116.3489	130.729	123.7	122.3633	136.2196	124.4	127.524	138.9181	1134.5029
2015	133.4	129.1967	150.9891	-871700	151.5894	177.4027	-871700	136.9978	162.3959	1041.9716
2016	97.08	102.0938	97.58722	151.2	129.743	145.5361	151.4	135.101	149.9478	1159.68892
2017	84.58	87.57509	89.08883	118.7	123.4651	142.5173	118.8	120.6144	127.0348	1012.37552
2018	79.93	82.75924	81.10779	115.1	115.5461	130.0364	111.9	111.6968	121.1449	949.22123
2019	92.78	97.80545	108.1783	114.6	120.5468	134.7427	116.5	124.7194	127.689	1037.56165
percentage %	0%	15.00%	84.60%	7.70%	0%	92.30%	7.70%	0%	92.30%	
Total	1216.82	1352.457	1462.636	986.877	1625.157	1839.413	1098.977	1622.089	1780.191	12982.5443

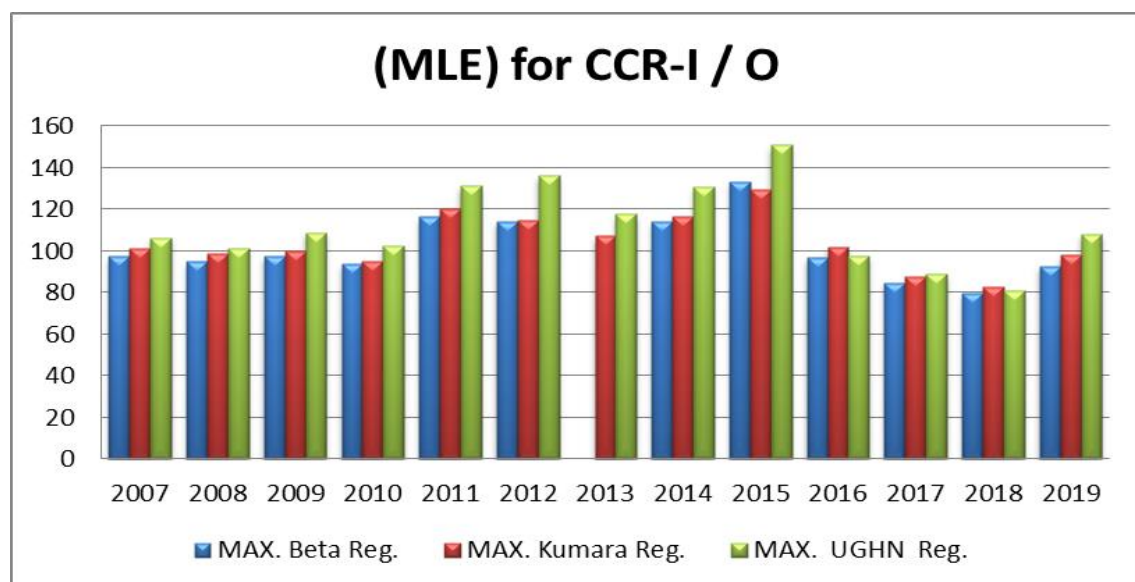


Chart 5.1. ML values of the regression models (Beta, Kumaraswamy, UGHN) constructed for the CCR-I/O model, 2007-2019.

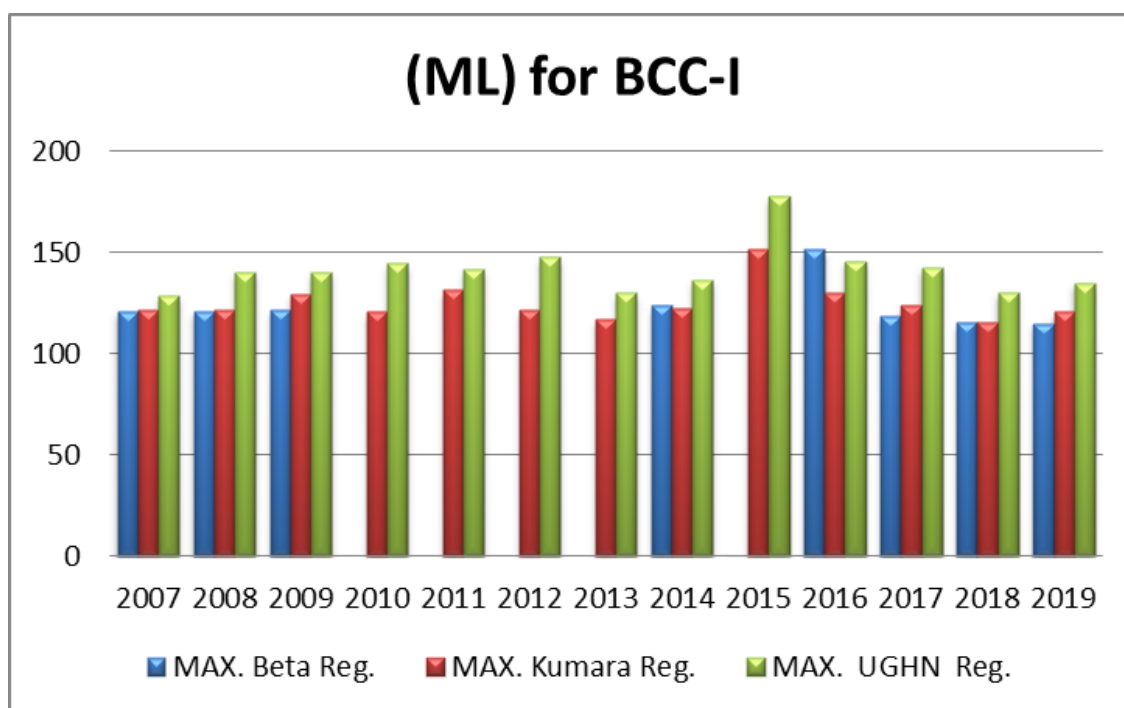


Chart 5.2. ML values of the regression models (Beta, Kumaraswamy, UGHN) constructed for the BCC-I model, 2007-2019.

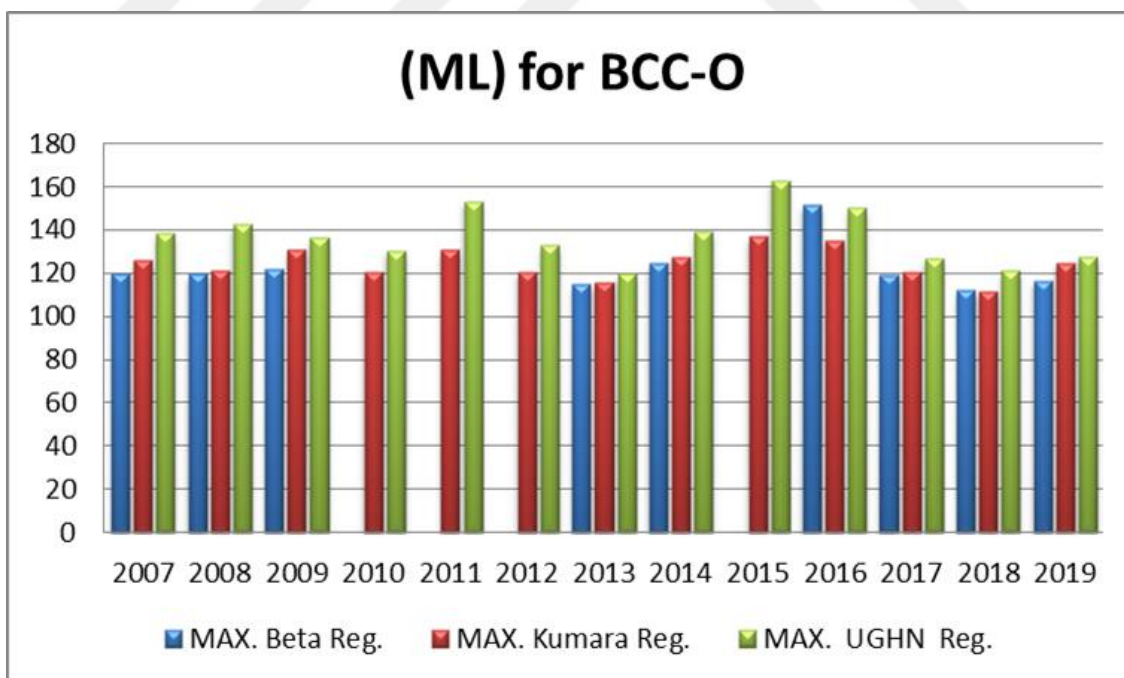


Chart 5.3. ML values of the regression models (Beta, Kumaraswamy, UGHN) constructed for the BCC-O model, 2007-2019.

5.3.2. The second angle: is by analyzing the results of tests for goodness of fit.

Each regression model was tested 117 times, 39 times for each of the three types of tests.

1. Beta regression achieved the lowest frequencies and percentages in all tests, as it achieved only six successes out of a total of 117 trials, i.e., a rate of 6%. It had two successes in Kolmogorov-Smirnov, three successes in Anderson-Darling, one success in Cramer-Von Mises, and one chance of success in all three tests simultaneously in the same model. In addition, the Beta distribution fails to find the regression equation several times, which are as follows:

A. In 2013, he failed to find the regression equation for the CCR-I / O model.

B. It failed in 2010, 2011, 2012, and 2013, respectively, to find the regression equation for the BCC-I model.

C. It failed in 2010, 2011, and 2012, respectively, to find the regression equation for the BCC-O model.

D. In the BCC-I model in 2015, the Beta regression equation was so far and illogical; also, in the same year in the BCC-O model.

2. Kumaraswamy regression achieved more frequencies and percentages than the Beta regression, as it achieved 29 successes out of the total tests, or a rate of 25%. In addition, it had 11 successes in Kolmogorov-Smirnov, eight successes in Anderson-Darling, ten successes in Cramer-Von Mises. It had six chances of achieving success in all three tests simultaneously on the same models.

3. (UGHN) regression obtained the highest frequencies and percentages from the other two regressions. It achieved 82 successes out of the total tests, or a rate of 70%. In addition, it reached 26 successes in Kolmogorov-Smirnov, 28 successes in Anderson-Darling, and 28 successes in Cramer-Von Mises. Thus, it had 23 chances of achieving success in all three tests simultaneously on the same models.

The frequency of the three regressions (Beta, Kumaraswamy, (UGHN)) had been the best in three tests simultaneously.

Beta Reg. Residuals	1
Kumar Reg. Residuals	6
UGHN Reg. Residuals	23

Table 5.41. The number and the percentage of successes that each regression model achieved as the best among the other regressions.

The Total No. of (frequency and percentage) of successes	Kolmogorov-Smirnov test		Anderson-Darling test		Cramer-von Mises test		Total Frequency	Total Percentage %
	Frequency	Percentage %	Frequency	Percentage %	Frequency	Percentage %		
Beta Reg. Residuals	2	0.051	3	0.077	1	0.0256	6	0.0513
Kumar Reg. Residuals	11	0.282	8	0.205	10	0.256	29	0.248
UGHN Reg. Residuals	26	0.6666	28	0.718	28	0.718	82	0.7
Total	39		39		39		117	

Table 5.42. The number of successes that each regression model achieved as the best among the other regressions.

2007 - 2019	One-sample Kolmogorov-Smirnov	One-sample Anderson-Darling test	One-sample Cramer-von Mises test
Beta Reg. Residuals	2	3	1
Kumar Reg. Residuals	11	8	10
UGHN Reg. Residuals	26	28	28

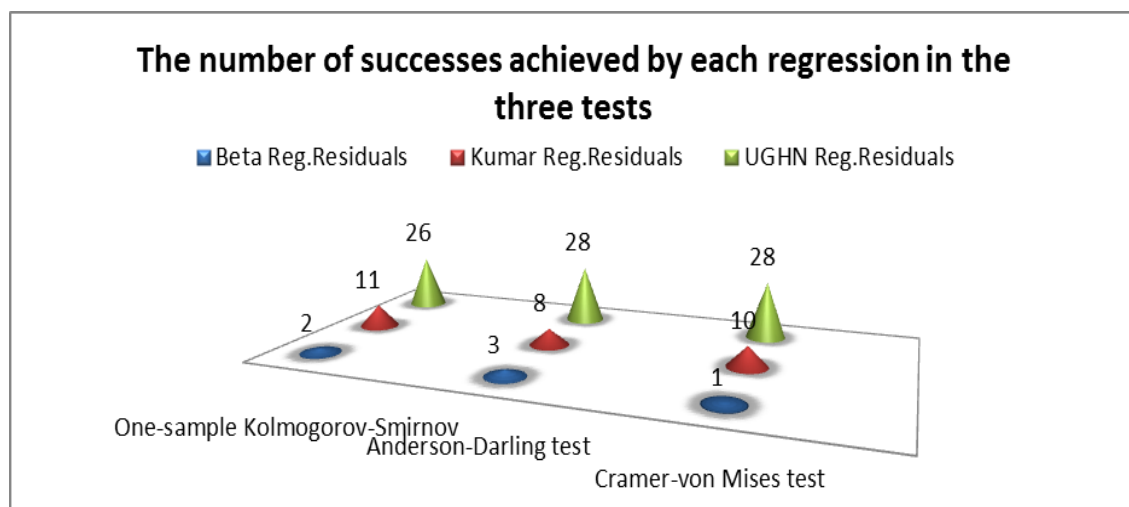


Chart 5.4. Representing the frequency of successes achieved by each regression model (Beta, Kumaraswamy, UGHN) in the three tests.

Table 5.43. Shows the Percentage of successes that each regression model achieved as the best among the other regressions.

2007 - 2019	One-sample Kolmogorov-Smirnov	One-sample Anderson-Darling test	One-sample Cramer-von Mises test
Beta Reg.Residuals	0.051	0.077	0.0256
Kumar Reg.Residuals	0.282	0.205	0.256
UGHN Reg.Residuals	0.6666	0.718	0.718

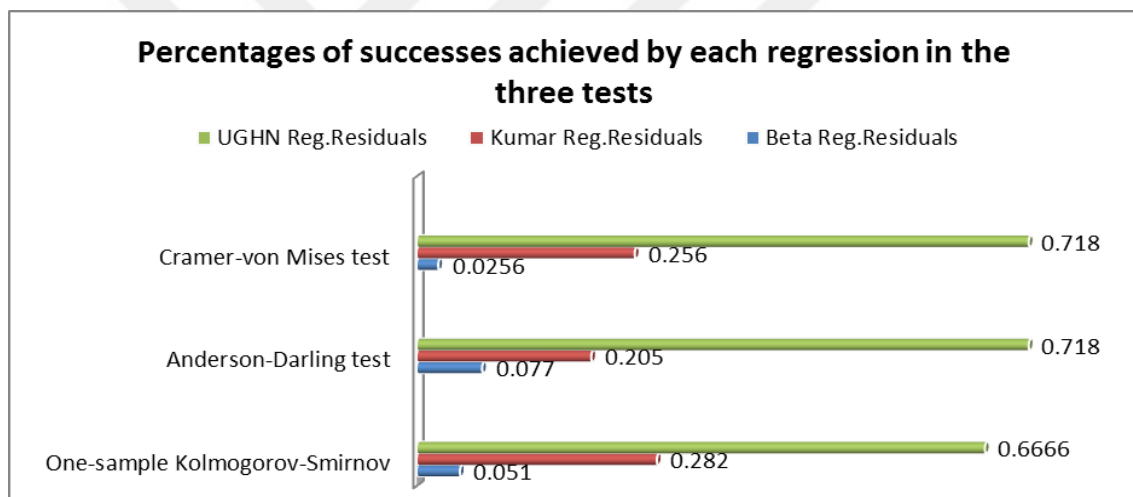


Chart 5.5. Representing the percentage of successes achieved by each regression of (Beta, Kumaraswamy, UGHN) in the three tests.

5.3.3. Concluding remarks on UGHN regression

From the above, we find that the generalized half-normal unit distribution (UGHN) gives the best regression analysis to the models (CCR-I/O, BCC-I, BCC-O) because its log-likelihood values higher than the other two distributions. In addition, the results obtained from tests for goodness of fit for residuals confirm the superiority of the regression equations obtained by the UGHN distribution over the rest of the other regressions. This indicates that the regression coefficients used in the regression equations by UGHN regression are the closest and most reasonable to predict the values of the dependent variable (Y representing the efficiency of firms). Furthermore, the UGHN regression model has more significant log-likelihood values than the Beta and Kuimaraswamy regression models in nearly all years. As a final comments, all the external covariates are significant on the efficiency of firms.

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