SPATIAL ANALYSIS OF MODERN CONTRACEPTIVE USE AMONGST WOMEN OF CHILD-BEARING AGE IN KENYA

PENINAH WANGARI MUIGAI

A Project Report Submitted to the Department of Public and Global Health in Partial Fulfilment of the Requirement for the award of the Degree of Master of Science in Medical Statistics of the University of Nairobi

DECLARATION OF ORIGINALITY FORM

Name of student………………………………… Peninah Wangari Muigai

Registration number…………………………… W62/34448/2019

Faculty…………………………………………... Health Sciences

Department………………………………………Public and Global Health

Course name……………………………………..Master of Science in Medical Statistics

Title of the work………………………………..Spatial analysis of modern contraceptive use amongst women of child-bearing age in Kenya

1. I understand what plagiarism is and I am aware of the University's policy in this regard.
2. I declare that this proposal is my original work and has not been submitted elsewhere for examination, award of degree or publication. Where other people's work or my own has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.
3. I have not sought or used the services of any professional agencies to produce this work.
4. I have not allowed and shall not allow anyone to copy my work with the intention of passing it off as his/her own work.
5. I understand that any false claim in respect of this work shall result in disciplinary action, in accordance with the University plagiarism policy.

Signature: **Date: 9/11/2023**

SUPERVISORS' APPROVAL

This project has been submitted for examination with our approval as supervisors.

Dr. Isaac C. Kipchirchir

Department of Mathematics

University of Nairobi

Role(s): Data curation and statistical model development.

Email: kipchirchir@uonbi.ac.ke

Signature Date: 9-11-2023

Dr. Peter Cherutich

Department of Public and Global Health

University of Nairobi

Role(s): Conceptualization, model design and report writing

Email:pcheru2013@gmail.com

Signature: Date: 8th November 2023

Dr. Oscar Ngesa

Department of Mathematics, Statistics and Physical Sciences

Taita Taveta University (TTU)

Email: oscanges@ttu.ac.ke

Role(s): Data curation, statistical model development and spatial analysis

Signature: Date: 8th November 2023

DEDICATION

To my daughter Ella Muthoni.

ACKNOWLEDGEMENT

I am grateful to the almighty God for seeing me through the completion of this project. I would like to pass my special gratitude to my mentor and supervisor Dr. Oscar Ngesa who played a major role in the development and completion of this project. His encouraging words amidst life challenges pushed me to finish this project. My sincere gratitude goes to my supervisors Dr.Isaac Kipchirchir and Dr. Peter Cherutich for their support, guidance and critics that have greatly contributed to the completion of this report.

To my classmates Robert Ofwete, Nicholas Muendo and Marianne Adhiambo, am grateful for being generous with your time and for the support you accorded me. Lastly, I would like to thank my family especially my husband Alfred Muthomi, my sisters Sabina Njeri and Rosemary Wanjiru who offered me immense support as I worked on this report.

LIST OF ABBREVIATIONS

AIDS	-	Acquired Immune Deficiency Syndrome
AOR	-	Adjusted Odds Ratio
CAR	-	Conditional Autoregressive model
CI	-	Credible Interval
DIC	-	Deviance Information Criterion
DHS	-	Demographic Health Survey
EAs	-	Enumeration Areas
EPSM	-	Equal Probability Selection Method
GLMM	-	Generalized Linear Mixed Model
HIV	-	Human Immunodeficiency Virus
ICPD	-	International Conference on Population and Development
IUD	-	Intrauterine Device
KDHS	-	Kenya Demographic Health Survey
K-HMSF	-	Kenya Household Master Sample Frame

KNH-UoN, ERC	-	Kenyatta National Hospital - University of Nairobi, Ethics and Research Committee
LCI	-	Lower Credible Interval
MDGs	-	Millennium Development Goals
MCMC	-	Markov Chain Monte Carlo
NACOSTI	-	National Commission for Science, Technology and Innovation
SDGs	-	Sustainable Development Goals
SNNPR	-	Southern Nations, Nationalities and Peoples' Region
SSA	-	Sub-Saharan Africa
STI	-	Sexually Transmitted Infections
UCI	-	Upper Credible Interval
UN	-	United Nations
UOR	-	Unadjusted Odds Ratio
WHO	-	World Health Organization

Table of Contents

LIST OF FIGURES

LIST OF TABLES

DEFINITIONS OF TERMINOLOGIES

Modern contraceptives: is a method of preventing pregnancy by using a procedure or a product.

Bayesian analysis: this inference approach involves applying prior beliefs to the expected data.

Prior distribution: refers to a probability distribution that represents what the model knows before seeing the data.

Posterior distribution: refers to a probability distribution that represents what the model knows after having seen the data.

Markov Chain Monte Carlo: is a technique that is used for integral approximations. It relies on computer simulations of random variables to produce an approximation technique that converges with the number of simulations produced.

Women of reproductive age: women who fall under the age bracket 15-49 years. The term is used interchangeably with women of childbearing age.

ABSTRACT

Background: Modern contraception is the use of a medical device or medical procedure to prevent pregnancy. In order to achieve the set Sustainable Development Goals (SDGs), there is need to control population growth. This can be achieved by advocating for use of modern contraceptives, which are effective in achieving family planning. This study aimed to evaluate spatial variation of modern contraceptive use, as well as determine significant factors associated with modern contraceptive use.

Methods: We used data from Kenya Demographic and Health Survey 2022 to evaluate factors associated with modern contraceptive use. Four models, which used the Bayesian approach to estimate model parameters, were fitted in WinBUGS software. These models were compared and used to deduce significant factors associated with modern contraceptive use.

Results: There was spatial variation of modern contraceptive use across the 47 counties of Kenya. North Eastern counties displayed low prevalence (<10%) of modern contraceptive use, while majority of the counties in the Central region displayed high prevalence (>50%) for modern contraceptive use. There were 3%-reduced odds of using modern contraceptives for every year increase in age. Islam had a 53% reduced odds for modern contraceptive use. Living with partner had the highest odds of utility for modern contraceptives (OR: 5.71; CI: 6.44-5.07). The odds of modern contraceptive use ranged from 1.32-1.47 across all levels of wealth index. Higher education recorded the highest odds (OR: 3.49; CI: 2.96-4.10) of modern contraceptive use compared to no education.

Conclusions: Given the regional disparities in modern contraceptive use, family planning programs that are county-specific need to be designed. Individual socio-economic and demographic factors played an important role in modern contraceptive use in Kenya. With devolution of health, the findings from this study can be used to inform policy makers at both the national and county level. Additionally, the national government can use this study to allocate resources to counties. Likewise, counties can use this study to budget for health and in particular reproductive health.

1. CHAPTER ONE: INTRODUCTION

1.1 Study Background

Contraception is the intentional prevention of pregnancy through use of various methods, devices, sexual practices, chemicals, drugs and surgical procedures. Methods of contraception are broadly categorized into two, namely: the traditional method and the modern method. The traditional method includes sexual abstinence - complete avoidance of sexual intercourse and periodic abstinence - avoiding sexual intercourse during fertile days of menstrual cycle. Coitus interruptus (withdrawal) is also classified as a traditional method of contraception (Jain & Muralidhar, 2011).

Globally, the need for contraception in 2020 was at fifty eight percent. This need has increased and has been satisfied by using modern contraceptives from seventy three point six percent in 2000 to seventy six point eight percent in 2020 (Bongaarts, 2020).

Only fifty five percent of women of reproductive age in sub-Saharan Africa and Western Asia have their family planning needs met (Bongaarts, 2020). The proportion of unmet contraceptive need in married and unmarried women in Kenya is fourteen percent and nineteen percent respectively (KNBS & ICF, 2023). The use of contraceptives is low among those who reside in rural areas, married before the age of 18, and had more than nine children (Kamuyango et al., 2020). Evaluation of county-specific coverage of modern contraception usage and exploration of the characteristics associated with their use provided a fuller knowledge of where the gap is per county in Kenya following devolution of health services. The national and county governments of Kenya, policy makers, non-governmental organizations and other relevant stakeholders can use this study to bridge identified gaps.

Worldwide, it has been estimated that approximately 35 per 1000 women had an abortion each year between 2010 – 2014 (Sedgh et al., 2016). These abortions have been exacerbated by non-use of contraceptives or use of ineffective contraceptives. The rate of unsafe abortion in the East African region stands at 36 per 1000 women, with 18 percent of these contributing to maternal deaths. Adolescents are the highly affected group with approximately sixty six percent at risk

(WHO, 2012). The leading cause for maternal death and mortality in Kenya is abortion. Every 12 out of 1000 women received post abortion care after undergoing unsafe abortions (Mohamed et al., 2015). This proportion could be higher as the reported rate was only for women who went to a health facility to be treated for abortion complications. One of the ways of reducing and curbing these abortions is advocating for use of modern contraceptives. Incidences of unwanted pregnancies and unsafe abortions will be greatly reduced and this will be in line with achieving the set sustainable development goals (SDGs). In order to accelerate achievement of the set goals, there is need to tackle and address unsustainable population growth (Jatana, 2020).

Various circumstances and needs for family planning warrant a difference in the type of contraceptive method used. Factors that influence the method used include the number of children desired, timing and spacing of births, marital status, and age of a woman at reproductive age. Choice of contraceptives is also dependent on whether a couple wants to delay pregnancy for a short or long period. Shorter acting methods are preferred where pregnancy is delayed for a few months or a couple of years. Awareness of the side effects of the different contraceptives is also an important factor in determining the type of contraceptives used (UN, 2019).

This study aims to identify geographic variances in factors related to modern contraceptives use among Kenyan women of reproductive age. In order to realize United Nations Foundation together with other agencies commitment of universal access to reproductive health care, it is important to know what factors affect contraceptive use in the different sub-national regions in Kenya. Decisions made will be more individualized and specific for counties, as opposed to generalization. The outcome of this study will show variations in uptake of modern contraceptive use, guide targeted interventions and inform policies aligned with maternal and reproductive health.

1.2 Statement of the research Problem

Kenya as a developing country has still not been able to achieve zero poverty, good health and well-being, which are part of the SDGs aimed at improving the standard of living for its people. This has not been achieved due to poor reproductive health practices and reduced health support caused by political instability, corruption and post-election violence. These factors have had a major setback in making progress towards achieving the set goals (Kibui et al., 2015). To date, there are still reported cases of teenage pregnancies, unwanted pregnancies, and unsafe abortions (KNBS & ICF, 2023).

On the other hand, the misconception of contraceptive use and lack of education has resulted in families bearing many children relative to their household income. The population of Kenya, as per the 2019 census, was forty seven point six million and yet the resources to support this growing population are very scarce (Kenya National Bureau of Statistics, 2019). The cycle of poverty is exacerbated by continued population growth that outcompetes the available resources. The need to control population growth is urgent and this can be achieved through advocacy of modern contraceptives use.

According to our knowledge, spatial analysis of contraception in Kenya has been done on women seeking post-abortion care. Unlike this current study, Mutua et al. (2019) only conducted their study on contraception only on women seeking post-abortion care. This current study focused on all women of age groups 15-49 years in Kenya. In addition, we used data collected in 2022 hence providing a recent update of modern contraceptive use. Another study that conducted spatial analysis of contraceptive use in Kenya was done on women living with HIV/AIDS (Okoli et al., 2019). First, similar to the study conducted by Mutua et al. (2019), this study was only limited to women living with HIV/AIDS. Secondly, the outcome of interest was status of contraceptive use. For the current study, our focus was on the status of modern contraceptive use as opposed to just any contraceptive method. Modern contraceptives are more effective in preventing pregnancy compared to traditional methods and with this, more informed policies can be made.

1.3 Justification

This research will serve as an important foundation for Kenya's constitutional mandate that everyone has a right to the best possible level of health, including reproductive health rights. By dissecting the factors affecting use of modern contraceptives, policies to support and enhance their use can be formulated and strengthened. In addition, with the devolution of health services, counties can use this study as reference in evaluating the performance of modern contraceptives uptake in their respective counties. This will trigger ways to improve uptake and will be in line with Kenya’s health policy, which aims to manage and control population growth (Kibui et al., 2015).

The study's target population was females between the ages of 15 and 49. This age group is economically productive, and any challenge imposed on it will pose a negative impact on the socio-economic growth of a country. Consequently, a negative socio-economic growth will delay the government's progress in achieving the set SDGS. Therefore, it is of great importance to ensure that women in this age bracket are well educated on family planning to make informed decisions about reproductive health.

This study was conducted in the forty-seven counties of Kenya and focused on spatial analysis of modern contraceptive use. Methodology used can be borrowed for future studies around the same topic or even other areas of research. Specifically, the application of binary logistic mixed effects model will not only provide the overall estimates for status of modern contraceptive use but as well as cluster estimates. Cluster estimates can be used to provide targeted interventions.

1.4 Research question

Did the use of modern contraceptives in Kenya vary across sub-national administrative units (counties) in 2022?

1.5 Objectives of the study

1.5.1 Broad Objective

To model factors influencing spatial variation of modern contraceptive use across the 47 counties of Kenya using KDHS 2022 data.

1.5.2 Specific Objectives

(i) To fit fixed effect model for factors affecting modern contraceptive use amongst women of childbearing age in Kenya in 2022.

(ii) To fit mixed effects model (non-spatial random effects) for factors affecting modern contraceptive use amongst women of childbearing age in Kenya in 2022.

(iii) To fit mixed effects model (spatial random effects) for factors affecting modern contraceptive use amongst women of childbearing age in Kenya in 2022.

(iv) To estimate county specific coverage of modern contraceptive use for all the 47 counties in Kenya using a conditional autoregressive (spatial) model.

2. CHAPTER TWO: LITERATURE REVIEW

This chapter reviewed literature on contraceptives. It captured an overall view of contraceptive use and preferred methods, the various factors affecting contraceptive use in different regions and spatial analysis methods used to estimate the coverage of contraceptives at sub-national level.

2.1 Contraceptive methods and preference

Modern contraception is defined as the interference with reproduction with medical products or procedures. Methods used for modern contraception can be categorized as either reversible or permanent. Temporary (reversible) methods can further be classified into short-term or long-term options. Short-term options include the pill, condom, injectable hormones, diaphragm or spermicides, while long-term methods encompass Intrauterine device (IUD) or hormonal implant. On the other hand, permanent (irreversible) methods include vasectomy and tubal ligation (Hubacher & Trussell, 2015).

Female sterilization is the most widely practiced form of contraception in the world. Forty five point two percent contraceptive users worldwide are on permanent and long-term methods, forty six point one percent rely on short-term methods while eight point seven percent rely on traditional methods (UN, 2019). In another study, condoms, oral contraceptive pills, withdrawal and rhythm were the choice of contraceptives amongst women around the world (Wang et al., 2020).

With a prevalence rate of nine point six percent, Sub-Saharan Africa (SSA) is the only region where injectables are the preferred method (UN, 2019). Ninety nine percent of women in Kenya are familiar with modern contraceptive methods while eight four percent are conversant with traditional methods. Male condoms are the most used method of contraceptives in Kenya (ninety six percent), followed by injectables at ninety five percent and oral pills at ninety four percent (Munga et al., 2014).

Preferred type of contraceptive method varied globally from country to country. While condom use was reported to have a prevalence of 89 percent in Greece, its prevalence in Nigeria was 2.7 percent. On the other hand, Iceland reported a prevalence of 59.5 percent for oral contraceptive pill while South Africa reported 1.9 percent prevalence for the same oral contraceptive pill (Wang et al., 2020). In the same study by Wang et al. (2020), it was reported that rhythm and withdrawal, which are ineffective methods of contraception, were still being used in some countries (China and

Greece) despite availability of highly effective methods of contraception today. There is therefore a huge gap for modern contraceptive use that needs to be addressed across the globe.

2.2 Unmet need of contraceptives use

Data based on 1247 surveys for 195 countries or areas around the world showed that as of 2019, 1.1 billion women between the ages of 15 and 49 require family planning. Those who use modern methods are 842 million while the remaining 80 million use traditional methods. However, there is a gap with 190 million people wanting to avoid pregnancy but not using any form of contraception (UN, 2019). Unmet need for contraceptive use varies across the Sub-Saharan Africa. It is highest in Sao Tome and Principe (thirty eight percent) as well as Ghana and Liberia (thirty six percent). Egypt has the lowest unmet need for contraception of twelve percent. Generally, SSA is lagging behind with nearly two-thirds of the countries having more than twenty-five percent unmet need for family planning (Sedgh & Hussain, 2014).

2.3 Spatial distribution of contraceptive use

Contraceptive use varied across the region in Rwanda and Kenya (Habyarimana & Ramroop, 2018; Okoli et al., 2019). In Rwanda, the use of contraceptives was higher in Northern Province districts and lower in Western province districts. On the other hand, the Kenyan study showed that contraceptive use amongst women living with HIV across the country varied and spatial analysis on intention to use contraceptive was not any different. There was spatial variation on intention to use contraceptives as demonstrated by a study done by Gilano and Hailegebreal (2021) in Ethiopia. Gambella, Benishangul, Addis Ababa, Southern Nations, Nationalities and Peoples' Region (SNNPR), Tigray, Amhara, and Oromia had the highest prevalence of intention to use contraceptives compared to other regions.

2.4 Factors affecting choice of contraceptives

In a study done by United Nations (UN, 2019), contraceptive choice of method varied from woman to woman depending on their needs at a given time. Method of contraceptive used was dependent on preference and needs of an individual. A woman who was not sexually active or did not have a partner went for short-term methods like use of condoms, oral pills as opposed to the long-term methods such as IUD (UN, 2019). When compared to short-term methods of contraception, a woman who intended to postpone conception or prevent future pregnancies was more likely to use an IUD (Mutua et al., 2019).

Availability and accessibility of a contraceptive also determined the type of contraceptive used. Individual's personal experience with certain contraceptives was another factor that informed choice of contraceptives used. How effective the method was, side effects and inconveniences associated with particular contraceptives made one prefer one contraceptive method to the other (UN, 2019). Eleven percent of women in Kenya for instance discontinued contraceptive use due to side effects associated with it (Munga et al., 2014).

2.5 Factors affecting contraceptive use

Studies in the past have shown that various demographic, socio-economic, and regional factors were significantly associated with utilization of contraceptives. Age, parity, religion, spouse approval, residence, education, wealth status, work, marital status, location of the health facility, family planning messages, and stock outs were some of the variables associated with contraceptive use. Age and parity were positively associated with the use of contraceptives. Use of contraceptives increased for every one year increase in age apart from the age group (40-49 years) (Nyarko, 2020). On the other hand, Munga et al. (2014) in Kenya and Habyarimana and Ramroop (2018) in Rwanda found that contraceptive use was higher amongst women with more children.

Contraception odds were lower for Muslim women in Ghana than for Christian women, and they were considerably lower for traditional and spiritual women (Nyarko, 2020). Mutua et al. (2019) and Habyarimana and Ramroop (2018) found that Catholics had lower rates of contraceptive use compared to non-Christians or Christians from other denominations. If a respondent or their spouse approved the use of contraceptives, then the likelihood of utilizing them was high (Palamuleni, 2013). Women who lived in cities in Ethiopia were more likely to use contraceptives compared to their rural counterparts (Admassu & Tegegne, 2021). Likewise, Munga et al. (2014) and Kamuyango et al. (2020) concluded that contraceptive use amongst women living in urban areas was higher.

Education and employment increased the odds of utilization of contraceptives. The likelihood of using contraceptives amongst women who attained a higher education level and were employed was higher compared to those who did not receive formal education and were unemployed in Ghana (Nyarko, 2020). In Kenya, the unmet need of family planning increased with decreasing level of education (Munga et al., 2014). The education level of a woman as well as that of her husband showed that a woman was most likely to use contraceptives if she and her partner attained a higher education (Kamuyango et al., 2020). Women with no education and primary education had a low prevalence for contraceptive use (Okoli et al., 2019).

Different studies had varying findings regarding the relationship between contraceptive usage and wealth index. For instance, in one study done in Kenya, the unmet need for contraceptives was notably high among women belonging to the lower socio-economic strata (Munga et al., 2014). In contrast, a study conducted in Ghana found that women hailing from more affluent households had a lower likelihood of using contraceptives compared to their counterparts from impoverished households (Nyarko, 2020).

There were lower odds of contraceptive use amongst women who were not married compared to those who were married or were cohabiting in Ghana (Kamuyango et al., 2020; Nyarko, 2020). Expectedly, women who had an easy access to provision of health services had a higher prevalence for using contraceptives in Ethiopia (Admassu & Tegegne, 2021). Women who were educated by a health care practitioner on contraceptives were positively influenced to use them (Admassu & Tegegne, 2021; Habyarimana & Ramroop, 2018).

2.6 Spatial analysis of contraceptive use

Spatial proximity, aggregation methods, cluster detection techniques, spatial interpolation and smoothing methods, multivariable spatial regression, Bayesian regression models and spatial autoregressive models are some of the spatial methods that are used in modelling spatial data (Auchincloss et al., 2012).

Habyarimana and Ramroop (2018) carried out a study in Rwanda to determine the spatial effects of socio-economic and demographic factors associated with contraceptive use in the country. Four models were developed where deviance information criterion (DIC) was used to determine the best model fit. The outcome of the models was contraceptive use status (whether a person uses contraceptives or not) hence it was modelled using binary logistic regression model. This model had categorical explanatory variables, which were fixed and assumed to have linear effects on the outcome variable. Model two not only included the explanatory variables but also factored in spatial effects and non-linear effects. In model three, all predictor variables were modelled as fixed effects and structured random effects as structured spatial effects, which catered for unobserved covariates. Model four included a structured spatial effect on model two. Estimation of parameters was done using Bayesian analysis. Diffuse priors were assigned to all fixed regression parameter while the second order Gaussian random walk priors were assigned to non-parametric continuous covariates. A Gaussian Markov random field specified as an intrinsic conditional autoregressive prior distribution was used to model the structured spatial effects. The prior distributions were combined with observed data to obtain posterior distribution, which were modelled to obtain a full Bayesian inference.

Nyarko (2020) carried out a Bayesian multilevel analysis in Ghana to identify geographic variations and socioeconomic factors influencing the adoption of modern contraceptives. To determine the regional modern contraceptive prevalence, a generalized linear model was fitted by region. A map was then generated by merging the fitted values with a shape file. Integrated Nested Laplace Approximations were used to estimate a Bayesian generalized mixed model, which examined how socioeconomic factors affected the use of contemporary contraceptives. Uniform priors were assigned to all regional level and population level parameters and a multilevel logistic regression model was fitted. Region of residence was used as a random effect in estimating a three multi-level logistic regression. Model one was used to determine the effects of socio-economic factors while models two and three were used for controlling demographic factors and regional aggregate factors respectively. The posterior distribution was used to obtain posterior means from which odds ratios and credible intervals were calculated.

Spatial analysis was conducted in a study done in Ethiopia where they wanted to evaluate intention to use contraceptives and the associated factors (Gilano & Hailegebreal, 2021). There were hierarchies at individual and community level hence a multilevel logistic regression model was done to account for the variations within and between communities. Community level variance was used to estimate intra-community correlation. Case to total proportion ratio was obtained by cross-tabulating weighted frequencies of dependent variables and cluster numbers. The results obtained were combined with coordinate data and using ArcGIS 10.7 the pattern of the data across the study area was obtained. Global Moran's Index was used to determine if intention to use contraceptives was dispersed as clustered or random. A hot spot analysis was also done to evaluate how intention to use contraceptives varied across the region. A hot spot showed high intention to use contraceptive while a cold spot showed low intention to use contraceptives. Spatial interpolation was employed using ordinary kriging and empirical Bayesian kriging and these helped to estimate intention to use contraceptives in areas where data was not collected. SaTscan statistics was used to determine significant clustering of intention to use contraceptives across the region. Four models were built for the multilevel binary logistic level analysis. The first model was an intercept only model and this model helped determine the variation among clusters. The second model included fixed effects variables while the third model included random effects variables. The full model was inclusive of both fixed effects, which were taken to be individual level variables, and random effects, which were community-level variables.

3. CHAPTER THREE: METHODOLOGY

3.1 Introduction

In this chapter, we consider techniques and strategies for this study. Anything related to the data including the study design, sampling criteria, data collection, and description of the study participants and data analysis were discussed in detail in this chapter. A description of the conceptual framework, the study variables, study area, and the study population is well explained in this chapter.

3.2 Study area

This study was conducted in Kenya, which covers an area of 580,367 square kilometers. Kenya is an East African country and is divided into 47 counties with a total population of approximately 47.6 million. The female population is approximately 24 million, while the male population is estimated to be 23 million (Kenya National Bureau of Statistics, 2019). The country has four cities: Mombasa, Kisumu, Nakuru, and Nairobi, which is its capital city. The Lake Victoria basin, the Rift Valley, the highlands, the eastern plateau forelands, the semiarid and arid parts of the north and south, and the coast are among the various geographical regions that make up Kenya. Tanzania, South Sudan, Ethiopia, the Indian Ocean, Somalia, and Uganda form its northern, eastern, southern, and western borders, respectively.

3.3 Study design

Analytical cross-sectional study design. Data was collected by interviewing individuals at one time point during the survey.

3.4 Study population

The study involved women aged 15-49 years.

3.4.1 Inclusion and exclusion criteria

Inclusion criteria

- Women aged 15-49 years.
- Individuals recruited and interviewed during the survey.

- Individuals that consented to the study.
- Women whose data is available on KDHS 2022.

Exclusion criteria

- Women outside age bracket 15-49 years

3.5 Sample size determination and sampling strategy

The 2022 Kenya Demographic Health Survey (KDHS) used a master sampling frame from Kenya Household Master Sample Frame (K-HMSF). The K-HMSF was developed by selecting 10,000 enumeration areas (EAs) out of 129,067 EAs obtained from the Kenya Population and Housing Census data. Four equal sub-samples were obtained randomly from the 10,000 EAs. The first sub-sample was used to obtain the sample that used in this survey. Each of the 47 counties in Kenya was divided into rural and urban. These strata were obtained for sampling. Nairobi and Mombasa were considered purely urban resulting in 92 strata.

A total of 42,300 households were divided into 25 households each, leading to 1692 clusters across the country. The rural areas were assigned 1062 clusters, while the urban areas were assigned 666 clusters. A two-stage sample design was used in 2022 KDHS. In the first stage, Equal Probability Selection Method (EPSM) was used to obtain the 1692 clusters. A household listing was obtained from all the selected clusters, forming the list of households used as the sampling frame for second stage of selection. In the second stage, 25 households were selected from each cluster. Some clusters had fewer than 25 households resulting in the selection of all households in these clusters. As a result, 42,022 households were included in the 2022 KDHS sample. The unit of analysis comprised 32,156 individual women of reproductive age (15-49 years) (KNBS, 2023).

3.6 Study variables and their method of measurement

Data was imported into STATA version 14.2 where the desirable variables were filtered. The data was weighted and summary description for each of the variables of interest was conducted. The outcome variable for this study was modern contraceptive use, which was measured at the individual level. This was generated from the variable "current use by method type," which had four levels: no method, folkloric method, traditional method, and modern method. A binary outcome variable was created by coding use of modern contraceptives as "1" and any other method as “0”. The sample size for individuals of other Christian denominations, Orthodox, Hindu and Traditionists was very small, so these categories were combined into one, forming a combined religion category.

Two predictor variables, age and parity, were measured as discrete variables. Dummy variables were created for all the other variables since they had more than one level. For these variables, “1” was assigned if response was true and “0” if otherwise. The specific references that were used were “no education” for the level of education, “other” for religion, “never in union” for marital status and “poorest” for the wealth index variable. Spatial characteristics, which included the forty- seven counties in Kenya, were included to assess spatial random effects. A detailed table of how the variables were coded has been demonstrated on appendix C.

3.7 Conceptual framework

The conceptual framework entailed two major components: the dependent variable and the independent variables. The dependent variable pertained modern contraceptive use status of women aged 15-49 years. The independent variables were classified into three major categories: individual characteristics, household characteristics, and spatial characteristics. Individuals were nested within households while households were nested within counties. Therefore, it was necessary to account for the hierarchical effect, leading to the adoption of a mixed effect binary logistic regression model for analysis.

Wealth index and residence variables constituted the household characteristics. Individual characteristics encompassed employment status, level of education, age, parity, religion and marital status. Spatial characteristics entailed the administrative boundaries of Kenya, which comprised its 47 counties.

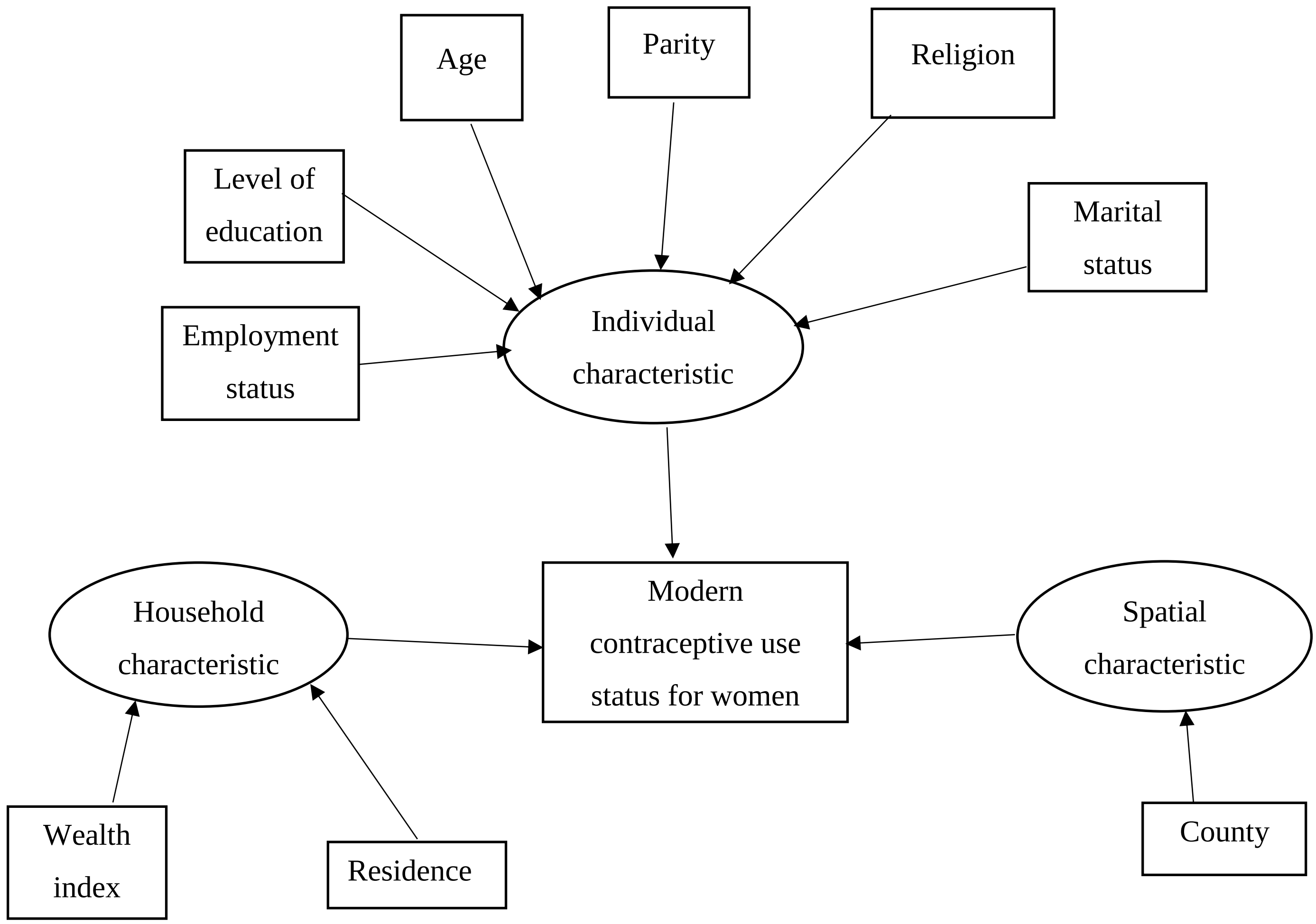


Figure 1: Relationship between dependent variable and independent variables

3.8 Data Collection

DHS is a program that conducts household surveys nationally. The data collection instrument comprise three questionnaires: the household questionnaire, the men's questionnaire, and the women's questionnaire. For this study, we retrieved data from the women's questionnaire where an interview was conducted among women aged 15-49 years.

3.9 Data processing and analysis

The data downloaded from DHS program was initially imported into STATA version 14.2 for processing. In STATA, the software was used to filter the desired variables. Subsequently, the data was exported to R version 4.1.3 and subjected to weighting. Data cleaning and manipulation was done in R. A descriptive data analysis was done in R after which, the data was exported into WinBUGS software version 1.4 for Bayesian analysis.

Four models were fitted to examine factors associated with modern contraceptive use. For all the four models, the dependent variable, which was status of modern contraceptives use, was constant. The variable had two responses; yes coded as “1” and no coded as “0” and hence followed a Bernoulli distribution. Modern contraceptive status in all the four models was represented by y_j.

Let y be the outcome for use of modern contraceptive use. “1” denoted “Success” and “0” denoted “failure” for use of modern contraceptives. Four models were fitted based on the objectives of the study.

3.9.1: To fit fixed effect model for factors affecting modern contraceptive use amongst women of childbearing age in Kenya in 2022.

In this model, we adjusted for the effect of fixed factors on modern contraceptive use. All variables (and levels) for: age, religion, residence, wealth index, marital status, employment status, education, and parity were fitted in a binary logistic regression model. The general equation for model one was:

$y \sim \text{Bernoulli}(p)$

$$\text{logit}(p) = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_k x_k \quad (3.1)$$

where,

p is the probability of modern contraceptive use,

β_o is the y intercept,

$\beta_1, \beta_2, \beta_3, \ldots, \beta_k$ are regression coefficients for the independent variables x_1, x_2, x_3 and x_k respectively.

3.9.2: To fit mixed effects model (non-spatial) for factors affecting modern contraceptive use amongst women of childbearing age in Kenya in 2022.

All variables (and levels) for: age, religion, residence, wealth index, marital status, employment status, education, and parity as well as the non-spatial random effect component were adjusted to form a binary logistic mixed model. The general equation for model two was:

$y \sim \text{Bernoulli}(p)$

$$\text{logit}(p) = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_k x_k + v_j \quad (3.2)$$

$v_j \sim N(0, \tau)$

where,

β_o is the y intercept,

$\beta_1, \beta_2, \beta_3, \ldots, \beta_k$ are regression coefficients for the independent variables x_1, x_2, x_3 and x_k respectively, and v_j is the non-spatial random effect.

v_j follows normal distribution with mean 0 and precision τ.

Non-informative priors were given to the coefficients, $\beta_i \sim N(0.0001, 0.0001)$

3.9.3: To fit mixed effects model (spatial) for factors affecting modern contraceptive use amongst women of childbearing age in Kenya in 2022.

Model three accounted for both fixed effects and spatial random effects. All variables (and levels) for: age, religion, residence, wealth index, marital status, employment status, education, and parity as well as the spatial random effect component were adjusted for to form a binary logistic mixed model. The spatial random effect component followed a conditional auto regression process (CAR). The general formula for model three was:

$y \sim \text{Bernoulli}(p)$

$$\text{logit}(p) = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_k x_k + u_j \quad (3.3)$$

$u_j \sim CAR(\rho, W)$

where;

β_o is the y intercept,

$\beta_1, \beta_2, \beta_3, \ldots, \beta_k$ are regression coefficients for the independent variables x_1, x_2, x_3 and x_k respectively, u_j is the spatial random effect,

Non-informative priors were given to the coefficients, $\beta_i \sim N(0.0001, 0.0001)$

CAR is conditional autoregressive distribution,

ρ is the spatial correlation parameter.

W is the neighborhood structure matrix.

3.9.4: To estimate county specific coverage of modern contraceptive use for all the 47 counties in Kenya using a conditional autoregressive (spatial) model.

Lastly, the fourth model accounted for fixed effects, non-spatial and spatial random effects. All variables (and levels) for: age, religion, residence, wealth index, marital status, employment status, education, and parity as well as the non-spatial and spatial random effect components were fitted to form a binary logistic mixed model. The general form of the model was:

$y \sim \text{Bernoulli}(p)$

$$\text{logit}(p) = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_k x_k + u_j + v_j \qquad (3.4)$$

$v_j \sim N(0, \tau)$

$u_j \sim CAR(\rho, W)$

where;

β_o is the y intercept,

$\beta_1, \beta_2, \beta_3 \ldots \beta_k$ are regression coefficients for the independent variables x_1, x_2, x_3 and x_k respectively, and u_j is the spatial random effect.

Non-informative priors were given to the coefficients, β_i,~N(0.0001,0.0001)

v_j follows normal distribution with mean 0 and precision τ.

u_j follows conditional autoregressive distribution.

ρ is the spatial correlation parameter.

W is the neighborhood structure matrix.

3.10 Model validation

The four models were compared using Deviance Information Criteria (DIC) value. The best model fit was determined by using the DIC value whereby, the smaller the DIC the better the model.

DIC is the sum of two components. The first component quantifies the model fit and it is measured through posterior expectation of the deviance, which is given by:

$$D(\theta) = -2\log(p(y|\theta) \tag{3.5}$$

The second component evaluates the complexity of the model and is given by:

$$P_D = E_{\theta|y}(D(\theta)) - D(E_{\theta|y}(\theta)) = \bar{D} - D(\bar{\theta}) \tag{3.6}$$

Given the first and second component,

$$DIC = \bar{D} + P_D$$

Where,

$\bar{D}$ is the average of the deviance for each data point in the data set.

P_D is the effective number of parameters in the model, which accounts for model complexity.

$\bar{D}$ is the average deviance across posterior samples of the model parameters.

$D(\bar{\theta})$ is the deviance at the posterior means of the parameters.

3.11 Sampling weights

To reduce sample variability, DHS data is usually selected with unequal probability. This introduces bias in the data making it unfit to be used for inference. Weighting needs to be applied to correct sampling design as well as differential response rates. In DHS surveys, sampling weights are usually provided but this need to be applied in the data for analysis. In this study, we used individual weight for women (v005) which was already provided.

The general formula for calculating weights in Bayesian models is:

$$\hat{p}_i = \frac{\sum\sum w_{ik} y_{ik}}{\sum\sum w_{ik}} \tag{3.7}$$

where,

$\hat{p}_i$ is the weighted proportion of the total population in area *i*.

w_{ik} is a weight, which is given by the inverse of the probability that the k^{th} person in the i^{th} area is sampled.

y_{ik} denotes the binary variable indicating if the k^{th} individual from area *i* has the outcome of interest (y_{ik} = 1) or (y_{ik} = 0)

3.12 Bayesian approach

Parameter estimation for all the four models was done using the Bayesian approach. For this study, it was impossible to collect status of modern contraceptive use for each woman living in Kenya. The ability of Bayesian approach to use prior information for parameter estimation was a desirable attribute. In Bayesian inference, the prior distribution and likelihood were specified and then we determined the posterior distribution.

3.12.1 Prior distribution

In all the four models, all parameters were assigned a prior distribution. This study used non-informative priors that had prior ignorance of the model parameters. All the priors followed a normal distribution with a mean of 0.0001 and precision of 0.0001. Hyperpriors for non-spatial and spatial random effects followed a gamma distribution since they could only assume positive values. These priors had little to no effect on the posterior distribution allowing for the data collected to make more inference on the posterior distribution.

3.12.2 Likelihood of the model

As seen above, y | (p) ~ Bernoulli (p) and the Bernoulli probability mass function is $p(y|p) = p^{y} \times (1-p)^{1-y}$

Then the likelihood for Bernoulli distribution was be given by:

$$L(p) = \prod_{i=1}^{n} p^{y} \times (1-p)^{1-y} \qquad (3.8)$$

Since from equation (3.4) $\text{Logit}(p) = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_k x_k + u_j + v_j$

Hence,

$\text{Logit}(p) = \log(p/1-p))$

$$p = \exp\{\beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_k x_k + u_j + v_j\}/(1+\exp\{\beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_k x_k + u_j + v_j\} \qquad (3.9)$$

Hence,

$L(p) = \prod_{i=1}^{n} p^{y} \times (1-p)^{1-y}$ can be written as;

$L(p) = \exp\{\beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ... + \beta_k x_k + u_j + v_j\}/(1+ \exp\{\beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ... + \beta_k x_k + u_j + v_j)\}^y \times (1+ \exp\{\beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ... + \beta_k x_k + u_j + v_j\}/(1+ \exp\{\beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ... + \beta_k x_k + u_j + v_j)\}^{1-y}$ (3.10)

3.12.3 Posterior distribution

A posterior distribution was generated through the product of the likelihood and prior information, which were specified in the model.

$P(j|\text{Data}) \propto P(\text{Data}|j) \times p_j$ (3.11)

Where,

$P(j|\text{Data})$ is the probability of posterior distribution given the data.

$P(\text{Data}|j)$ is the likelihood of the model.

p_j is prior information.

3.12.4 Sampling algorithm

Markov chain Monte Carlo (MCMC) technique was used to simulate the process in WINBUGS statistical software using an algorithm. The model was replicated several times using pre-determined number of iterations (100,000) in a markovian process to enhance model convergence and improve on validity of the estimates. Gibbs sampling was applied to obtain sequence of observations.

3.12.5 Significance of predictor

For this study, significance of a predictor was determined using credible interval. A predictor was significant if the value 1 was not included in the interval.

$H_{O:}\ e^{\beta 1} = 1$ vs. $H_{1:}\ e^{\beta 1} \neq 1$

Where,

H_O is the null hypothesis and was given by exponent of the regression coefficient (odds ratio) being equal to 1.

H_1 is the alternative hypothesis and was given by the exponent of the regression coefficient (odds ratio) not being equal to 1.

3.13 Numerical simulation using WinBUGS software 14

WinBUGS version 14 software was used to estimate the unknown parameters in the model by applying the Bayesian approach. Present study assumed non-informative priors that followed normal distribution for all the coefficients. The non-informative priors were combined with the likelihood of the data to form posterior distribution from which inference was made. Initial values were set to zero for all the model parameters.

Data for the independent variables was coded in R version 4.1.3 software as "1" or "0" then exported to WinBUGS as text file. The likelihood of the model was specified based on the dependent variable. Since the dependent variable was binary, it was specified to follow Bernoulli distribution. The probability of status of modern contraceptive use was set to be between 0 and 1. The four different models (fixed effects, binary logistic mixed model (non-spatial), binary logistic mixed model (spatial) and CAR spatial model) were analyzed independently. WinBUGS could not handle many parameters with one logical function hence the variables were divided into three parts A[i], B[i] and C[i]. Age and the different levels of religion were included in the A[i] category. Marital status was specified under B[i] while C[i] specified wealth index, level of education, residence and parity. The non-spatial random effect and spatial random effect were specified under C[i] category. A[i], B[i] and C[i] were then combined and linked to the link function (logit) for Bernoulli distribution.

The codes were run by clicking on the word Model on the top panel followed by specification, which opened a specification tool. The word "model" on the code was highlighted followed by clicking "check model" on the specification tool. WinBUGS gave a response on the bottom left corner "model is syntactically correct" indicating validation of this step. The word "list" on the data section in WinBUGS was then highlighted followed by clicking "load data" on the specification tool. There was a response on the bottom left corner "data loaded". "Compile" on the specification tool was then clicked and this was followed by the response "model compiled". The word list on initials was then highlighted followed by clicking load "inits" button on the specification tool. A response "model is initialized" was observed on the bottom left corner of the software.

3.14 Sampler running

On the menu bar inference was clicked followed by sample. This resulted in opening of the "sample monitor tool". At the "node", all parameters being monitored were typed in one by one and word set was selected each time. Up to this point WinBUGS had already created a posterior distribution. On the menu bar, "Model" was clicked followed by "Update" which opened an "Update Tool" window. We set the update value, which is number of posterior samples to 100,000 and monitored the iteration box update until it reached the 100,000th iteration. WinBUGS used Markov chain Monte Carlo (MCMC) technique to obtain the samples.

3.15 Posterior inference

After getting the 100,000 posterior samples all the set nodes were specified at the sample monitor tool by putting an asterisk symbol inside the "node" box. We then selected 5000 to be the number of initial values that we wanted dropped in the "beg" box. This process is known as "burn in". This is aimed at reducing the effect of the initial values from the true parameter estimates. We were then able to obtain the summary statistics of the posterior distribution. Convergence was assessed using trace plots.

Output data for stats obtained from WinBUGS was filtered and columns for node, median and credible interval were obtained. Names for the node column, which initially had parameter names, were changed to the variable name corresponding to each parameter. The variable names were then grouped into their classifications and the reference for each classification stated. WinBUGS output produced results in log form so the results were transformed into the real values through exponentiation of the results.

3.16 Minimization of errors and biases

This was achieved by checking for any duplicates in the data set and getting rid of double entries. Unwanted outliers were filtered and those that were erroneous were removed. We also checked for data entry errors and standardized variables with discrepancies.

3.17 Ethical considerations

Ethical approval was granted after review from Kenyatta National Hospital - University of Nairobi, Ethics and Research Committee **(KNH-UoN, ERC).**

Data from KDHS 2022 was acquired through a formal request to the Demographic and Health Surveys **(DHS)** Program, stating clearly the intended purpose for using the survey data.

Confidentiality of the data was maintained and no effort was made to identify any household or individual respondent interviewed in the survey. Any DHS micro-level data was not re-distributed either directly or within any tool or dashboard.

3.18 Limitations of the study

This current study had several limitations. First, since the study was cross-sectional we could not draw the causal relationship between modern contraceptive use and independent variables. Secondly, this study used data from KDHS 2022 which was based on self-report data. Third, our findings were only limited to data collected in KDHS 2022. Other unknown factors like cultural practices could have affected modern contraceptive use.

4. CHAPTER FOUR: RESULTS

4.1 Introduction

The results of this study are presented in this chapter. The different sections include the socio-demographic characteristics, the association between covariates and modern contraceptive use in the fixed effects model, the non-spatial mixed effects model and the spatial mixed effects model. Results from the full conditional autoregressive model with both the non-spatial and spatial random effects was also presented in this chapter. Finally, unsmoothed and smoothed maps showing the prevalence of modern contraceptive use across the counties in Kenya was displayed.

4.2 Sociodemographic characteristics of the study participants

Table 1 shows background characteristics of the study participants. Approximately 38 percent of women used modern contraceptives and 58 percent did not use any method for family planning. Majority of the study participants resided in the rural areas (61.5%) compared to the urban areas (38.5%). The proportion of women working and those not working was 48.1 percent and 51.8 percent respectively.

More than half of the study participants had a primary and secondary school education. Women who were not educated were the least recorded (12%) followed by those who had a higher education (15%).

Approximately half of the women in this study were married and a quarter of the women were never in a union. The least proportion of women (2%) were those who were divorced.

There was little variation among women in the different age categories. Interestingly, majority of the women were observed in the first age category of 15-19 years (20%) while the least number of women were registered in the last age category of 45-49 years (8%). Proportions in all the other age categories did not vary as much.

There was little proportion variation in wealth index category. Women who were classified as poorest and richer had the highest representation of 22% from each of the levels. Both poorer and richest categories had a representation of 18% while 19% of the women were middle class.

Only 27.15 % of women in this study had more than three children. The highest proportion of women did not have any child (27.41%) followed by those who had one child (15.92%). The proportion of women having more than nine children was very small (<1%) with only one woman recorded to have fifteen children.

There was a small variation in the number of women who participated in this study across the 47 counties in Kenya. The highest proportion of women was recorded among women who lived in Nairobi (2.94%) while the lowest proportion of women was observed in Taita Taveta county (1.5%). Majority of the counties (32) recorded between 2-3% women and only a few of the counties (15) recorded women below 2%.

Only 23.4 % of women in this study had more than three children. The highest proportion of women did not have any child (28.1%) followed by those who had one child (17.3%). The proportion of women having more than nine children was very small (<1%) with only one woman recorded to have fifteen children.

There was a small variation in the number of women who participated in this study across the 47 counties in Kenya. The highest proportion of women was recorded among women who lived in Nairobi (2.94%) while the lowest proportion of women was observed in Taita Taveta county (1.5%). Majority of the counties (32) recorded between 2-3% women and only a few of the counties (15) recorded women below 2%.

Table 1. Descriptive data for the study participants

Variable	**Frequency**	**Percent**	**Variable**	**Frequency**	**Percent**
Dependent variable			***Household characteristics***		
Contraceptive use by method	**32,156**	**100**	**Place of residence**	**32,156**	**100**

No method	18694	58.14	Urban	12,386	38.52
Folkloric method	53	0.16	Rural	19,770	61.48
Modern method	12,195	37.92			
Individual characteristics			**Wealth index**	**32,156**	**100**
Religion	**32156**	**100**	Poorest	7,073	22
Catholic	5,665	17.62	Poorer	5,742	17.86
Protestant	10,777	33.51	Middle	6,345	19.73
Evangelical churches	6,981	21.71	Richer	7,160	22.27
African instituted churches	2,542	7.91	Richest	5,836	18.15
Orthodox	81	0.25			
Islam	4,852	15.09	**County**	**32,156**	**100**
Hindu	24	0.07	Mombasa	749	2.33
Traditionists	93	0.29	Kwale	711	2.21
No religion/atheists	357	1.11	Kilifi	742	2.31
Other	784	2.44	Tana River	641	1.99
			Lamu	675	2.1
Current marital status	32156	100	Taita Taveta	483	1.5
Never in union	10,048	31.25	Garissa	641	1.99
Married	16,454	51.17	Wajir	745	2.32
Living with partner	1,858	5.78	Mandera	723	2.25
Widowed	1,020	3.17	Marsabit	535	1.66
Divorced	558	1.74	Isiolo	623	1.94
Separated	2,218	6.9	Meru	602	1.87
Respondent currently working	32156	100	Tharaka Nithi	535	1.66
No	16,681	51.88	Embu	584	1.82
Yes	15,475	48.12	Kitui	671	2.09
			Machakos	699	2.17
Highest educational level	32156	100	Makueni	720	2.24
No education	3,836	11.93	Nyandarua	590	1.83
Primary	11,807	36.72	Nyeri	529	1.65
Secondary	11,634	36.18	Kirinyaga	605	1.88

Higher	4,879	15.17	Murang'a	557	1.73
			Kiambu	668	2.08
Total children ever born	32,156	100	Turkana	644	2
0	8,813	27.41	West pokot	756	2.35
1	5,119	15.92	Samburu	615	1.91
2	5,115	15.91	Trans Nzoia	713	2.22
3	4,374	13.6	Uasin Gishu	731	2.27
4	3,088	9.6	Elgeyo-Marakwet	591	1.84
5	2,064	6.42	Nandi	721	2.24
6	1,377	4.28	Baringo	687	2.14
7	937	2.91	Laikipia	576	1.79
8	563	1.75	Nakuru	782	2.43
9	368	1.14	Narok	744	2.31
10	193	0.6	Kajiado	660	2.05
11	90	0.28	Kericho	779	2.42
12	39	0.12	Bomet	778	2.42
13	12	0.04	Kakamega	810	2.52
14	3	0.01	Vihiga	721	2.24
15	1	0	Bungoma	841	2.62
Respondent's current age	32,156	100	Busia	768	2.39
15-19	6,404	19.92	Siaya	674	2.1
20-24	5,762	17.9	Kisumu	761	2.37
25-29	5,443	16.93	Homa Bay	712	2.21
30-34	4,561	14.19	Migori	777	2.42
35-39	4,354	13.54	Kisii	708	2.2
40-44	3,100	9.64	Nyamira	635	1.97
45-49	2,532	7.88	Nairobi	944	2.94

4.3 Deviance Information Criteria

The four models were compared using DIC value. The best model is the one with the lowest DIC. The binary logistic mixed model with both non-spatial and spatial random effects had the lowest DIC value of 34433.900. Binary logistic regression model with only fixed effects had the highest DIC value of 35110.200. The binary logistic mixed models for both non-spatial and spatial random effects had the same DIC value of 34434.700.

Table 2. A comparison of DIC for fixed effects binary logistic regression model, binary mixed model (non-spatial random effect), binary mixed model (spatial random effect) and binary mixed model (non-spatial and spatial random effects).

	Fixed effects model	Mixed model (Non-spatial random effect)	Mixed model (Spatial random effect)	Mixed model (Non-spatial and spatial random effects)
Dbar	35086.700	34369.700	34367.300	34365.400
Dhat	35063.200	34300.200	34299.900	34298.900
pD	23.472	67.418	67.418	68.496
DIC	35110.200	34434.700	34434.700	34433.900

4.4 Association between covariates and modern contraceptive use; a comparison of fixed effects, non-spatial mixed effects and spatial mixed effects models

All categories of the variables age, marital status, wealth index, employment status, education level and parity were significantly associated (credible intervals was not inclusive of 1) with modern contraceptive use in the fitted models for fixed effects, non-spatial mixed effects and spatial mixed effects.

Across the three models, estimates for all the variables (and categories) were comparable except for education level where the median odds estimates were higher in the fixed effects model (OR ranged from 4.44-5.24) compared to the non-spatial mixed effect model (OR ranged from 2.96-3.54) and the spatial mixed effect model (OR ranged from 2.9-3.47). Those who attained a higher education level had the highest odds of modern contraceptives across the three models compared to those with no education. For fixed effects model, higher education had a 5.24 times increased odds of modern contraceptive use compared to those with no education. Secondary and primary level education had increased odds of 4.5 and 4.4 respectively. For the non-spatial mixed effects and spatial mixed effects models, there was an increased odds of 3.54 and 3.47 respectively among those who attained a higher education. Likewise, the odds of modern contraceptives use for the two models was approximately 2.9 times higher for both secondary and primary levels of education.

Living with a partner recorded the highest median odds of modern contraceptives use followed by married in all the three models. The median odds of modern contraceptive use among women living with partner was approximately five times more compared to those who were never in a union across the three models. The widowed registered lowest median odds of 1.6 for modern contraceptives use across all the models compared to those who were never in a union.

The odds of modern contraceptives use ranged between 1.48-1.72 in fixed effects model, 1.33-1.47 in non-spatial mixed effects model and 1.32-1.47 in spatial mixed effects model for the wealth index variable. The odds of modern contraceptive use was approximately 60% higher among the employed compared to the unemployed.

Residential area displayed a discrepancy in the significance for modern contraceptive use across the three models. Place of residence was only found to be insignificant (OR : 0.96; CI: 0.9-1.03) in the fixed effects model. Non-spatial random effects model and spatial random effects model registered residential area to be significant (OR: 1.13; CI: 1.04-1.21) and (OR: 1.13; CI : 1.05-1.22) respectively. Those who resided in the urban areas had 13% increased odds of modern contraceptives use in both the non-spatial mixed effects model and spatial mixed effects model compared to those in the rural areas.

Religion displayed a discrepancy for significance in the fixed effects model. The variability in the significance is adjusted for by the random effects. Compared to non-spatial mixed effects model and spatial mixed effects model, the levels protestant (OR: 1.14; CI: 1.00-1.35) and catholic (OR: 1.18; CI: 1.00-1.4) were found to be significant in the fixed effects model only. Across all the three models, only Islam and combined religion (other Christians, Hindus, traditionists and orthodox) were found to be significant. Islam had reduced odds of 0.31 for modern contraceptive use in the fixed effects model. For non-spatial mixed effects, model and spatial mixed effects model, the odds for modern contraceptive use in Islam was 53% less compared to other. Those in combined religion had a 41% reduced odds for modern contraceptives use compared to other in all the three models.

Generally, there was minimal discrepancy in the three models with a higher similarity index displayed in non-spatial mixed effects model and spatial mixed effects model. The table below highlights a comparison of the estimates (medium value) and the accompanying 2.5% and 97.5% credible intervals for fixed effects model, non-spatial mixed effects model and spatial mixed effects model.

Table 3. Estimates and 95% Credible Interval (CI) levels for fixed effects model, non-spatial mixed effects model and spatial mixed effects model

	Fixed effects model			Non-spatial mixed effects model			Spatial mixed effects model		
variable	**median**	**LCI (2.5%)**	**UCI (97.5%)**	**median**	**LCI (2.5%)**	**UCI (97.5%)**	**median**	**LCI (2.5%)**	**UCI (97.5%)**
Intercept	0.04	0.03	0.05	0.07	0.05	0.09	0.07	0.05	0.09
Age	0.97	0.97	0.98	0.97	0.96	0.97	0.97	0.96	0.97
Marital status									
Never in union (ref)	-	-	-	-	-	-	-	-	-
Married	5.2	4.81	5.61	5.48	5.06	5.95	5.47	5.04	5.92
Living with partner	5.84	5.2	6.55	5.7	5.06	6.42	5.72	6.46	5.07
Widowed	1.6	1.35	1.89	1.67	1.41	1.99	1.67	1.4	1.99
Divorced	2.44	1.96	3.03	2.72	2.18	3.38	2.72	2.16	3.39
Separated	3.1	2.78	4.47	3.07	2.73	3.43	3.06	2.73	3.43
wealth index									
Poorest	-	-	-	-	-	-	-	-	-
Poorer	1.48	1.35	1.62	1.35	1.23	1.48	1.34	1.22	1.48
Middle	1.55	1.42	1.7	1.39	1.26	1.52	1.38	1.26	1.52
Richer	1.72	1.56	1.9	1.47	1.33	1.63	1.47	1.32	1.63
Richest	1.66	1.47	1.88	1.33	1.17	1.51	1.32	1.17	1.5
Employment status									
Employment status_no	-	-	-	-	-	-	-	-	-
Employment status_yes	1.68	1.59	1.78	1.63	1.54	1.73	1.63	1.54	1.73
Education level									
No education	-	-	-	-	-	-			
Primary	4.44	3.92	5	2.96	2.6	3.35	2.9	2.53	3.32
Secondary	4.5	3.96	5.14	2.96	2.58	3.39	2.91	2.5	3.36
Higher	5.24	4.53	6.08	3.54	3.03	4.11	3.47	2.95	4.08

Residence									
Rural	-	-	-	-	-	-	-	-	-
Urban	0.96	0.9	1.03	1.13	1.04	1.21	1.13	1.05	1.22
Parity									
Parity	1.18	1.15	1.2	1.21	1.18	1.23	1.21	1.18	1.23
Religion									
Other(ref)	-	-	-	-	-	-	-	-	-
Protestant	1.14	1	1.35	0.97	0.82	1.16	0.98	0.81	1.16
Catholic	1.18	1	1.4	1.03	0.86	1.23	1.04	0.86	1.24
Evangelical churches	1.15	0.98	1.37	0.96	0.81	1.15	0.97	0.8	1.15
African instituted churches (AIC)	0.99	0.83	1.19	0.87	0.72	1.05	0.87	0.72	1.05
Islam	0.31	0.26	0.38	0.47	0.38	0.57	0.47	0.38	0.58
Atheists	0.93	0.7	1.24	0.79	0.59	1.06	0.79	0.58	1.06
Combined religion	0.59	0.39	0.88	0.59	0.39	0.89	0.59	0.38	0.89

4.5 Random effects model statistics summary

Table 4 presents a summary statistics for the non-spatial random effect and spatial random effect. The variability in the expected number of women who use modern contraceptives between counties unexplained by the estimates (the fixed effect of the model) is explained by both the non-spatial random effect and spatial random effect. The median for the non-spatial random effect precision was 10.7 with a 95% CI of 4.31-41.14. Spatial random effect had a precision median of 6.49 and a 95%CI of 3.17-18.01.

Table 4. Spatial and non-spatial random effects statistics summary

Precision	**median**	**LCI (2.5%)**	**UCI (97.5%)**
Non-spatial random effect	10.7	4.31	41.14
Spatial random effect	6.49	3.17	18.01

4.6 Predictors for modern contraceptive use for binary logistic mixed model – Combined spatial and non-spatial random effects

Protestant (OR:0.96; CI:0.82-1.16), catholic ((OR:1.02; CI:0.86-1.24), evangelical churches (OR:0.95; CI:0.81-1.15), African instituted churches (OR:0.86; CI:0.72-1.05), and atheists (OR:0.78; CI:0.58-1.05) were the only insignificant variables not associated with modern contraceptive use in this model.

Age, Islam and combined religion were associated with decreased odds of modern contraceptive use. There was 3% reduced odds of modern contraceptive use for every one year increase in age (OR: 0.97; CI: 0.96-0.97). Compared to other, combined religion (Hindu, Orthodox, Traditionists and other Christians) were 41% less likely to use modern contraceptives (OR: 0.59; CI: 0.38-0.88). Islam had a 53% reduced odds for modern contraceptives use compared to other (OR: 0.47; CI: 0.39-0.58).

All levels of marital status recorded an increased odds (OR>1) of modern contraceptive use compared to those who had never been in a union. Living with partner had the highest odds of utility for modern contraceptives (OR: 5.71; CI: 6.44-5.07) followed by those in marriage (OR: 5.46; CI: 5.05-5.93). Widowed registered the lowest odds (OR: 1.67; CI: 1.40-1.98) of modern contraceptive use compared to never in union.

All categories of wealth index had relatively the same odds of modern contraceptives compared to poorest. The odds of modern contraceptive use ranged from 1.32-1.47. The highest odds for modern contraceptive use was richer (OR: 1.47; CI: 1.32-1.63). Richest had the lowest odds of using modern contraceptives (OR: 1.32; CI: 1.16-1.50).

Employed had a 63% increased odds of modern contraceptives use compared to unemployed (OR: 1.63; CI: 1.54-1.73). Parity was positively associated with utility of modern contraceptives. There was 21%-increased odds of modern contraceptives for every child born to a woman.

The odds of modern contraceptive increased with increase in the level of education. Higher education recorded the highest odds (OR: 3.49; CI: 2.96-4.10) of modern contraceptive use compared to no education. Both primary and secondary had increased odds of approximately 2.9 for modern contraceptives use.

The table below highlights the estimates (medium value) and the accompanying 95% CI for the binary logistic CAR model.

Table 5. Estimates and 95% CI for binary logistic mixed model: Combined non-spatial and spatial random effects

CAR model			
variable	**median**	**LCL (2.5%)**	**UCI (97.5%)**
Intercept	0.07	0.05	0.09
Age	0.97	0.96	0.97
Marital status			
Never in union (ref)	-	-	-
Married	5.46	5.05	5.93
Living with partner	5.71	6.44	5.07
Widowed	1.67	1.40	1.98
Divorced	2.71	2.17	3.38
Separated	3.06	2.74	3.43
Wealth index			
Poorest(ref)	-	-	-
Poorer	1.34	1.22	1.47
Middle	1.38	1.26	1.52
Richer	1.47	1.32	1.63
Richest	1.32	1.16	1.50
Employment status			
Employment status_no (ref)	-	-	-
Employment status_yes	1.63	1.54	1.73

Education level			
No education (ref)	-	-	-
Primary	2.91	2.53	3.34
Secondary	2.92	2.51	3.38
Higher	3.49	2.96	4.10
Residence			
Rural (ref)	-	-	-
Urban	1.13	1.05	1.22
Parity			
Parity	1.21	1.18	1.23
Religion			
Other(ref)	-	-	-
Protestant	0.96	0.82	1.16
Catholic	1.02	0.86	1.24
Evangelical churches	0.95	0.81	1.15
African instituted churches (AIC)	0.86	0.72	1.05
Islam	0.47	0.39	0.58
Atheists	0.78	0.58	1.05
Combined religion	0.59	0.38	0.88

4.7 Crude and adjusted weighted prevalence of modern contraceptive use by county

There was little variation in the prevalence of modern contraceptive use when the crude and adjusted prevalence were compared. Overall, the prevalence of modern contraceptive use varied across the 47 counties in Kenya. Only 7 out of 47 counties had a prevalence of above 50 percent, with Embu county recording the highest prevalence at 56.19 percent. High prevalence rates were generally observed in counties making up the central region of Kenya: Nyeri (50.60%), Kirinyaga (50.23%), and Kiambu (50.75%). In addition to Embu, Meru county (50.44%) in the Eastern region also had a high prevalence for modern contraceptive use. Elgeyo Marakwet and Uasin Gishu counties in the formerly rift valley region also recorded prevalence above 50 percent at 52.2 percent and 50.23 percent respectively.

Four counties out of forty-seven counties recorded a prevalence of less than 10 percent. The lowest prevalence for modern contraceptive use was observed in Mandera (1.21%). Garissa followed with a prevalence of 2.75 percent. Wajir and Marsabit counties had a prevalence of 4.05 percent and 7.54 percent respectively.

Table 6. Crude and Adjusted Prevalence for Modern Contraceptive use in Kenya

	CRUDE PREVALENCE (WEIGHTED)			ADJUSTED PREVALENCE (WEIGHTED)		
County	UOR	LCI	UCI	AOR	LCI	UCI
Turkana	24.22	18.73	29.71	24.56	21.24	27.26
Marsabit	4.83	2.28	7.37	7.54	5.54	9.92
Mandera	1.44	0.45	2.44	1.21	0.67	2.01
Wajir	2.22	0.74	3.69	4.05	2.83	5.61
West Pokot	21.27	12.66	29.88	21.85	19.21	24.64
Samburu	24.11	18.06	30.16	23.45	20.54	26.52
Isiolo	20.55	16.75	24.35	19.18	16.61	21.97
Baringo	38.22	32.71	43.73	40.16	36.93	43.46
Elgeyo Marakwet	50.74	46.18	55.30	52.20	48.52	55.86
Trans Nzoia	46.36	41.58	51.14	47.64	44.34	50.99
Bungoma	43.80	40.35	47.26	43.73	40.74	46.67
Garissa	8.32	2.21	14.43	2.75	2.00	3.67
Uasin Gishu	49.10	45.41	52.78	50.23	46.95	53.52
Kakamega	46.60	43.26	49.93	46.09	43.11	49.12
Laikipia	44.54	40.12	48.96	44.23	40.64	47.76
Busia	39.40	35.63	43.18	41.21	37.97	44.42
Meru	51.31	46.43	56.20	50.44	46.88	53.95
Nandi	44.03	39.68	48.37	48.30	44.96	51.69
Siaya	33.09	28.96	37.21	35.36	32.12	38.67
Nakuru	46.58	42.31	50.86	47.57	44.40	50.77
Vihiga	36.64	32.98	40.30	34.52	31.52	37.58
Nyandarua	41.76	36.83	46.69	44.84	41.13	48.53
Tharaka Nithi	51.34	47.72	55.00	49.73	45.92	53.43
Kericho	45.19	41.50	48.89	45.35	42.27	48.43
Kisumu	42.62	38.63	46.62	42.67	39.53	45.84
Nyeri	51.17	46.42	55.92	50.60	46.88	54.37
Tana river	20.22	14.12	25.23	19.68	17.47	23.13
Kitui	44.22	38.64	49.80	46.08	42.70	49.49
Kirinyaga	49.94	46.39	53.48	50.23	46.60	53.81
Embu	57.19	52.53	61.85	56.19	52.61	59.70
Homa Bay	45.50	40.85	50.14	44.94	41.79	48.10
Bomet	38.87	33.93	43.80	39.07	36.03	42.17
Nyamira	44.10	39.24	48.96	44.40	40.93	47.87
Narok	42.58	39.36	45.80	41.84	38.67	44.98
Kisii	49.42	45.53	53.32	49.33	46.05	52.65
Murang'a	47.04	41.52	52.56	49.16	45.42	52.89
Migori	45.09	40.62	49.55	46.09	42.90	49.30
Kiambu	49.87	45.74	53.99	50.75	47.28	54.15

Machakos	46.97	42.63	51.32	45.45	42.23	48.66
Kajiado	45.13	39.62	50.63	41.69	38.40	44.94
Nairobi	40.79	36.84	44.73	42.84	39.87	45.82
Makueni	41.77	37.54	46.00	42.96	39.66	46.26
Lamu	29.75	23.88	35.62	27.90	25.69	29.96
Kilifi	31.95	28.05	35.85	31.27	28.30	34.30
Taita Taveta	47.43	42.29	52.58	47.03	43.05	51.02
Kwale	24.26	20.12	28.40	25.55	22.61	28.57
Mombasa	29.67	25.09	34.30	31.29	28.21	34.48

4.8 Maps for the unadjusted and adjusted prevalence for modern contraceptive use

Two maps; unadjusted and adjusted maps were generated. The unadjusted map was generated using R software. Crude data was grouped by counties and instructed to use values for "modern" to draw the map. On the other hand, the adjusted map was generated in WinBUGS software using modelled data for prevalence of modern contraceptive use.

Adjusted and unadjusted prevalence of modern contraceptive use as demonstrated by the two maps was generally the same. Out of the 47 counties, only two counties (Isiolo and Tana River) showed a discrepancy. In the two counties, the unadjusted map showed that the prevalence of modern contraceptive use was between 20-30 percent while the adjusted map displayed a prevalence of 10-20 percent for both counties. This was attributed to a rounding off effect.

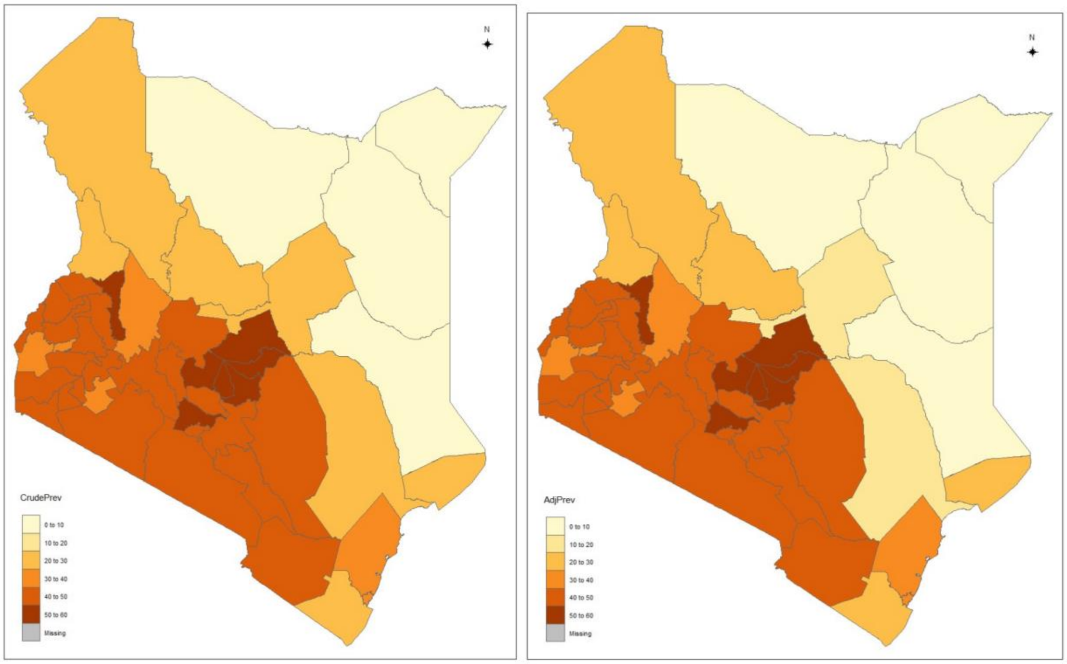


Figure 2: Unadjusted (left) and adjusted (right) prevalence of modern contraceptive use in Kenya

[1]

[1] The unadjusted map was generated by using crude values of modern contraceptive use in each of the counties. Adjusted map was obtained after adjusting for age, wealth index, employment, residence, parity, religion, marital status, education, and counties.

5. CHAPTER FIVE: DISCUSSION

The primary aim of this study was to model the factors influencing spatial variation of modern contraceptive use across the 47 counties of Kenya in 2022. The best model fit was the binary logistic mixed model with both non-spatial and spatial random effects fitted: The model had the lowest DIC value (34433.900). We can therefore deduce that both spatial and non-spatial random effects were important in explaining the findings from this study. Our findings revealed spatial variation in modern contraceptives use across the 47 counties in Kenya. Notably, counties like Embu, and Meru exhibited a high prevalence for modern contraceptive use while counties such as Wajir, Mandera and Marsabit showed a considerably lower prevalence. This finding concurs with previous studies where contraceptive use varied across the regions (Habyarimana & Ramroop, 2018). These geographical disparities indicate the regional imbalance in the utilization of modern contraceptives, emphasizing the need for region-specific strategies to address these disparities (Tsui et al., 2017). From the maps, the discrepancy in prevalence for Isiolo and Tana River occurs due to a rounding off effect. After rounding off there is no discrepancy (prevalence is 20%).

Age demonstrated an inverse relationship with modern contraceptive use implying that older women were less likely to use modern contraceptives, which could be attributed to reduced sexual activity in this group. These findings are supported by other study findings (Palamuleni, 2013). Conversely, in Ghana, contraceptive use increased with age except for the age group 40-49 (Nyarko, 2020). Although older women may perceive to have a low risk of getting pregnant, it is important for them to be knowledgeable that they may get pregnant and thus need to use modern contraceptives to prevent unintended pregnancies (Black et al., 2009). Modern contraceptive use should thus cut across all age groups despite the level of risk of getting pregnant.

Married women and those who lived with their partner were more likely (OR: 5.46; CI: 5.05-5.93) to use modern contraceptives. This could be attributed to being more sexually active and hence the need for family planning. The findings in this study were comparable to other studies (Habyarimana & Ramroop, 2018; Kamuyango et al., 2020; Nyarko, 2020). These findings are however worrying because the prevalence of premarital sex among unmarried women worldwide is approximately 42 percent and yet there is low contraceptive utilization in these group of women (Wang et al., 2020). The risk of unwanted pregnancies among those who are not married, widowed and divorced needs to be addressed. Programs, campaigns and National strategies that promote modern contraceptive use across all marital status levels are paramount.

In this study, there was no specific trend in the wealth index hierarchy for use of modern contraceptives. Previous studies yielded different findings; while contraceptive use increased with the family's wealth in Rwanda, women from affluent households in Ghana had lower probabilities of using contraceptives compared to those from impoverished households (Habyarimana & Ramroop, 2018; Nyarko, 2020).

Unemployed women were less likely to use modern contraceptives compared to their employed counterparts, possibly due to economic empowerment of employed women, enabling them to afford family planning services (Nyarko, 2020). Other research corroborates with this finding (Nyarko, 2020). Women need to be empowered to counter gender inequality and power imbalance in order for them to participate in important decision making including choice to use modern contraceptives (Some et al., 2021). A poor understanding of the risk of pregnancy and health concerns related to side effects of contraceptives are major contributors of contraceptives non-use (Darroch & Singh, 2013). Other than advocating for individual education, the government of Kenya needs to facilitate health education campaigns to curb the barriers of using modern contraceptive methods.

Higher levels of education was positively associated (OR: 3.49; CI: 2.96-4.10) with modern contraceptive use compared to no education. This suggests that education empowers women with knowledge and access to family planning. Similar findings were observed in other studies conducted by Kamuyango et al. (2020), Nyarko (2020) and Okoli et al. (2019). Additionally, a higher unmet need of contraception was associated with decreased education level (Munga et al., 2014). Given the importance of education in enhancing modern contraceptives use, factors that may lead to early dropout by girls need to be addressed. Ensuring separate sanitary facilities for boys and girls and improving the quality of schools can encourage girls to stay in schools (Buyinza & Hisali, 2014).

Modern contraception was higher among women residing in urban areas, which could be attributed to easier accessibility to modern contraceptives. These findings are consistent with other studies (Admassu & Tegegne, 2021; Kamuyango et al., 2020; Munga et al., 2014). Access to modern contraceptives need to be improved both globally and in different countries including Kenya through increased allocation of funding (Darroch & Singh, 2013). Health care services in the rural facilities can be improved through decentralization of services, interdisciplinary and team based working as well as flexibility of roles (Rygh & Hjortdahl, 2007).

Surprisingly, Islam (OR: 0.47; CI: 0.39-0.58) and combined religion (OR: 0.59; CI: 0.38-0.88) were the only levels in religion found to be significant associates of modern contraceptive use. Combined religion, which consisted of Traditionists, Hindus, other Christians and Orthodox, had small sample sizes, which led to their grouping to improve the accuracy of the results. The findings of this study regarding Islam being less likely (OR:0.47; CI:0.39-0.58) to use modern contraceptives is comparable to a study conducted in Ghana (Nyarko, 2020). Despite religious norms discouraging contraceptive use especially amongst Catholics, a woman's religious affiliation did not significantly affect her current contraceptive use. In fact, the compatibility for women using contraceptives and them being religious is strong (Rachel K & Dreweke, 2011). From this finding, we can conclude that religion hardly influences the use of modern contraceptives and it should therefore not be a major focus area when it comes to policy implication.

Generally, the Kenyan government can adopt findings from this study and implement policies on reproductive health based on these findings to improve the prevalence of modern contraceptives in all sub-national regions of Kenya. Not only will this expedite achievement of universal access to sexual and reproductive health, but sustainable economic growth and decent productive employment for all will be attained.

6. CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

The findings from this study show that modern contraceptive use in Kenya is relatively low, with only 7 out of 47 counties having a prevalence above 50 percent. Regional disparities in modern contraceptives use are notable, with North Eastern counties at a disadvantage compared to counties in the central region of Kenya. The inequality in reproductive health services across the counties need to be addressed. The government of Kenya can use this study as a guide to allocate resources paying more attention to North Eastern counties where prevalence for modern contraceptive use was less than 10 percent.

The findings from this study will help inform policy makers, reproductive health experts and other relevant stakeholder about the status of modern contraceptive use in Kenya. This study reinforces sustainable development goal number 3 and further emphasizes access to sexual reproductive and health-care services, including family planning, information and education as well as integration of reproductive health into national strategies programs. Family planning programs should put more emphasis and empower women who are unemployed, uneducated and those who are not in a union to bridge the gap of modern contraceptive use. Lastly, the study's findings show the need for county specific programs in order to address the regional disparity in modern contraception.

REFERENCES

Admassu, M., & Tegegne, A. S. (2021). Factors Affecting Contraceptive Use in Ethiopian: A Generalized Linear Mixed Effect Model. *Ethiopian Journal of Health Sciences*, *31*(3), 457–466. https://doi.org/10.4314/ejhs.v31i3.2

Auchincloss, A. H., Gebreab, S. Y., Mair, C., & Diez Roux, A. V. (2012). A review of spatial methods in epidemiology, 2000-2010. *Annual Review of Public Health*, *33*, 107–122. https://doi.org/10.1146/annurev-publhealth-031811-124655

Black, A., Yang, Q., Wen, S. W., Lalonde, A. B., Guilbert, E., & Fisher, W. (2009). Contraceptive Use Among Canadian Women of Reproductive Age: Results of a National Survey. *Journal of Obstetrics and Gynaecology Canada*, *31*(7), 627–640. https://doi.org/10.1016/S1701-2163(16)34242-6

Bongaarts, J. (2020). United Nations Department of Economic and Social Affairs, Population DivisionWorld Family Planning 2020: Highlights, United Nations Publications, 2020. 46 p. *Population and Development Review*, *46*(4), 857–858. https://doi.org/10.1111/padr.12377

Buyinza, F., & Hisali, E. (2014). Microeffects of Women’s Education on Contraceptive Use and Fertility: The Case of Uganda. *Journal of International Development*, *26*(6), 763–778. https://doi.org/10.1002/jid.2915

Darroch, J. E., & Singh, S. (2013). Trends in contraceptive need and use in developing countries in 2003, 2008, and 2012: An analysis of national surveys. *The Lancet*, *381*(9879), 1756–1762. https://doi.org/10.1016/S0140-6736(13)60597-8

Gilano, G., & Hailegebreal, S. (2021). Assessment of intention to use contraceptive methods with spatial distributions and associated factors among women in Ethiopia: Evidence from EDHS 2016. *Archives of Public Health*, *79*(1), 109. https://doi.org/10.1186/s13690-021-00631-2

Habyarimana, F., & Ramroop, S. (2018). Spatial Analysis of Socio-Economic and Demographic Factors Associated with Contraceptive Use among Women of Childbearing Age in Rwanda. *International Journal of Environmental Research and Public Health*, *15*(11), 2383. https://doi.org/10.3390/ijerph15112383

Hubacher, D., & Trussell, J. (2015). A definition of modern contraceptive methods. *Contraception*, *92*(5), 420–421. https://doi.org/10.1016/j.contraception.2015.08.008

Jain, R., & Muralidhar, S. (2011). Contraceptive Methods: Needs, Options and Utilization. *The Journal of Obstetrics and Gynecology of India*, *61*(6), 626–634. https://doi.org/10.1007/s13224-011-0107-7

Jatana.N, Currie. A. (2020). *Hitting the targets*. Population Matters.

Kamuyango, A., Hou, W.-H., & Li, C.-Y. (2020). Trends and Contributing Factors to Contraceptive Use in Kenya: A Large Population-Based Survey 1989 to 2014. *International Journal of Environmental Research and Public Health*, *17*(19), 7065. https://doi.org/10.3390/ijerph17197065

Kenya National Bureau of Statistics (Ed.). (2019). *2019 Kenya population and housing census*. Kenya National Bureau of Statistics.

Kibui, A.W., Nyaga, G.W., Ngesu, L.M., Mwaniki, B., & Kahiga, R.M. (2014). Health Policies In Kenya And The New Constitution For Vision 2030. International Journal of Educational Science and Research. *International journal of scientific research*.

KNBS and ICF. 2023. *Kenya Demographic and Health Survey 2022*. Key Indicators Report. Nairobi, Kenya, and Rockville, Maryland, USA: KNBS and ICF.

Mohamed, S. F., Izugbara, C., Moore, A. M., Mutua, M., Kimani-Murage, E. W., Ziraba, A. K., Bankole, A., Singh, S. D., & Egesa, C. (2015). The estimated incidence of induced abortion in Kenya: A cross-sectional study. *BMC Pregnancy and Childbirth*, *15*(1), 185. https://doi.org/10.1186/s12884-015-0621-1

Munga, B., Nyanjom, O., Onsomu, E., & Mwabu, G. (2014). *Kenya*. 303–335.

Mutua, M. M., Achia, T. N. O., Manderson, L., & Musenge, E. (2019). Spatial and socio-economic correlates of effective contraception among women seeking post-abortion care in healthcare facilities in Kenya. *PloS One*, *14*(3), e0214049. https://doi.org/10.1371/journal.pone.0214049

Nyarko, S. H. (2020). Spatial variations and socioeconomic determinants of modern contraceptive use in Ghana: A Bayesian multilevel analysis. *PloS One*, *15*(3), e0230139. https://doi.org/10.1371/journal.pone.0230139

Okoli, M. L., Alao, S., Ojukwu, S., Emechebe, N. C., Ikhuoria, A., & Kip, K. E. (2019). Predictive and spatial analysis for estimating the impact of sociodemographic factors on contraceptive use among women living with HIV/AIDS (WLWHA) in Kenya: Implications for policies and practice. *BMJ Open*, *9*(1), e022221. https://doi.org/10.1136/bmjopen-2018-022221

Palamuleni, M. E. (2013). Socio-economic and demographic factors affecting contraceptive use in Malawi. *African Journal of Reproductive Health*, *17*(3), 91–104.

Rachel K, J., & Dreweke, J. (2011). *Countering Conventional Wisdom: New Evidence on Religion and Contraceptive Use*. Guttmacher Institute.

Rygh, E., & Hjortdahl, P. (2007). *Continuous and integrated health care services in rural areas. A literature study*. *7*(3), 1–10.

Sedgh, G., Bearak, J., Singh, S., Bankole, A., Popinchalk, A., Ganatra, B., Rossier, C., Gerdts, C., Tunçalp, Ö., Johnson, B. R., Johnston, H. B., & Alkema, L. (2016). Abortion incidence between 1990 and 2014: Global, regional, and subregional levels and trends. *The Lancet*, *388*(10041), 258–267. https://doi.org/10.1016/S0140-6736(16)30380-4

Some, S. Y. M., Pu, C., & Huang, S.-L. (2021). Empowerment and use of modern contraceptive methods among married women in Burkina Faso: A multilevel analysis. *BMC Public Health*, *21*(1), 1498. https://doi.org/10.1186/s12889-021-11541-x

Tsui, A. O., Brown, W., & Li, Q. (2017). Contraceptive Practice in Sub-Saharan Africa. *Population and Development Review*, *43*(Suppl Suppl 1), 166–191. https://doi.org/10.1111/padr.12051

United Nations. (2019). *Contraceptive Use by Method 2019*. https://doi.org/10.18356/1bd58a10-en

World Health Organization. (2012). *Unsafe abortion incidence and mortality: global and regional levels in 2008 and trends during 1990-2008* (No. WHO/RHR/12.01). World Health Organization.

Wang, M.-Y., Temmerman, M., Zhang, W.-H., Fan, Y., Mu, Y., Mo, S.-P., Zheng, A., & Li, J.-K. (2020). Contraceptive and reproductive health practices of unmarried women globally, 1999 to 2018: Systematic review and meta-analysis. *Medicine*, *99*(49), e23368. https://doi.org/10.1097/MD.0000000000023368

APPENDICES

Questionnaire

2022 KENYA DEMOGRAPHIC HEALTH SURVEY (KDHS) WOMAN'S QUESTIONNAIRE WITH VARIABLES OF INTEREST

A: AGE

110	In what month and year were you born?	MONTH .... [ ][ ] DON'T KNOW MONTH .... 98 YEAR .... [ ][ ][ ][ ] DON'T KNOW YEAR 9998
111	How old were you at your last birthday? COMPARE AND CORRECT 110 AND/OR 111 IF INCONSISTENT.	AGE IN COMPLETED YEARS ..... [ ][ ]

B: COUNTY AND RESIDENCE

102	What county were you born in? REFER TO COUNTY CODE LIST IN INTERVIEWER'S MANUAL	COUNTY CODE .... [ ][ ] OUTSIDE OF KENYA 96
104	How long have you been living continuously in (NAME OF CURRENT CITY, TOWN OR VILLAGE OF RESIDENCE)? IF LESS THAN ONE YEAR, RECORD '00' YEARS.	YEARS .... [ ][ ] ALWAYS/NEVER MOVED .... 95 VISITOR 96

C: LEVEL OF EDUCATION

113	Have you ever attended school?	YES .... 1 NO 2
114	What is the highest level of school you attended: primary, secondary/'A' level, college, university,or vocational?	PRIMARY .... 1 SECONDARY/ 'A' LEVEL .... 2 MIDDLE LEVEL COLLEGE (CERTIFICATE/ DIPLOMA) .... 3 UNIVERSITY .... 4 VOCATIONAL TRAINING .... 5 INFORMAL EDUCATION (MADRASA/ ADULT BASIC) 6
115	What is the highest (standard/grade/form/year) you completed at that level? IF COMPLETED LESS THAN ONE YEAR AT THAT LEVEL, RECORD '00'.	STANDARD/GRADE/FORM/YEAR .. [ ][ ]

D: RELIGION

130	What is your religion?	CATHOLIC .... 01 PROTESTANT .... 02 EVANGELICAL CHURCHES .... 03 AFRICAN INSTITUTED CHURCHES .... 04 ORTHODOX .... 05 OTHER CHRISTIAN .... 06 ISLAM .... 07 HINDU .... 08 TRADITIONISTS .... 09 NO RELIGION/ ATHEISTS .... 10 OTHER RELIGION ____________ 96 (SPECIFY)

E:PARITY

201	Now I would like to ask about all the births you have had during your life. Have you ever given birth?	YES .... 1 NO 2
202	Do you have any sons or daughters to whom you have given birth who are now living with you?	YES .... 1 NO 2
203	a) How many sons live with you? b) And how many daughters live with you? IF NONE, RECORD '00'.	a) SONS AT HOME .... [ ][ ] b) DAUGHTERS AT HOME .... [ ][ ]
204	Do you have any sons or daughters to whom you have given birth who are alive but do not live with you?	YES .... 1 NO 2
205	a) How many sons are alive but do not live with you? b) And how many daughters are alive but do not live with you? IF NONE, RECORD '00'.	a) SONS ELSEWHERE .... [ ][ ] b) DAUGHTERS ELSEWHERE .... [ ][ ]
206	Have you ever given birth to a boy or girl who was born alive but later died? IF NO, PROBE: Any baby who cried, who made any movement, sound, or effort to breathe, or who showed any other signs of life even if for a very short time?	YES .... 1 NO 2

207	a) How many boys have died? b) And how many girls have died? IF NONE, RECORD '00'.	a) BOYS DEAD . . . . [ ][ ] b) GIRLS DEAD . . . . [ ][ ]
208	SUM ANSWERS TO 203, 205, AND 207, AND ENTER TOTAL. IF NONE, RECORD '00'.	TOTAL LIVE BIRTHS . . . . [ ][ ]
209	CHECK 208: Just to make sure that I have this right: you have had in TOTAL _____ births during your life. Is that correct? YES [ ] NO [ ] → PROBE AND CORRECT 201-208 AS	

F: STATUS OF MODERN CONTRACEPTIVE USE

301	Now I would like to talk about family planning - the various ways or methods that a couple can use to delay or avoid a pregnancy. Have you ever heard of (METHOD)?	
01	Female Sterilization. PROBE: Women can have an operation to avoid having any more children.	YES . . . . 1 NO 2
02	Male Sterilization. PROBE: Men can have an operation to avoid having any more children.	YES . . . . 1 NO 2
03	IUD. PROBE: Women can have a loop or coil placed inside them by a doctor or a nurse which can prevent pregnancy for one or more years.	YES . . . . 1 NO 2
04	Injectables. PROBE: Women can have an injection by a health provider that stops them from becoming pregnant for one or more months.	YES . . . . 1 NO 2
05	Implants. PROBE: Women can have one or more small rods placed in their upper arm by a doctor or nurse which can prevent pregnancy for one or more years.	YES . . . . 1 NO 2
06	Pill. PROBE: Women can take a pill every day to avoid becoming pregnant.	YES . . . . 1 NO 2
07	Male Condom. PROBE: Men can put a rubber sheath on their penis before sexual intercourse.	YES . . . . 1 NO 2
08	Female Condom. PROBE: Women can place a sheath in their vagina before sexual intercourse.	YES . . . . 1 NO 2

09	Emergency Contraception. PROBE: As an emergency measure, within 3 days after they have unprotected sexual intercourse, women can take special pills to prevent pregnancy.	YES . . . . . 1 NO 2
10	Standard Days Method. PROBE: A woman uses a string of colored beads to know the days she can get pregnant. On the days she can get pregnant, she uses a condom or does not have sexual intercourse.	YES . . . . . 1 NO 2
11	Lactational Amenorrhea Method (LAM). PROBE: Up to 6 months after childbirth, before the menstrual period has returned, women use a method requiring frequent breastfeeding day and night.	YES . . . . . 1 NO 2
12	Rhythm Method. PROBE: To avoid pregnancy, women do not have sexual intercourse on the days of the month they think they can get pregnant.	YES . . . . . 1 NO 2
13	Withdrawal. PROBE: Men can be careful and pull out before climax/ ejaculation.	YES . . . . . 1 NO 2
14	Have you heard of any other ways or methods that women or men can use to avoid pregnancy?	YES, MODERN METHOD __________ A (SPECIFY) YES, TRADITIONAL METHOD __________ B (SPECIFY) NO . . . . . Y

302	CHECK 232: NOT PREGNANT OR UNSURE ☐ PREGNANT ☐	
303	Are you or your partner currently doing something or using any method to delay or avoid getting	YES . . . . . 1 NO 2
304	Are you or your partner sterilized? IF YES: Who is sterilized, you or your partner?	YES, RESPONDENT STERILIZED ONLY . . 1 YES, PARTNER STERILIZED ONLY . . . . 2 YES, BOTH STERILIZED . . . . . 3 NO, NEITHER STERILIZED 4
305	CHECK 304: RESPONDENT STERILIZED ONLY ☐ PROCEED TO 307. CIRCLE CODE 'A' AND FOLLOW THE SKIP INSTRUCTION. PARTNER STERILIZED ONLY ☐ PROCEED TO 307. CIRCLE CODE 'B' AND FOLLOW THE SKIP INSTRUCTION. BOTH STERILIZED ☐ PROCEED TO 307. CIRCLE CODE 'A' AND CODE 'B' AND FOLLOW THE SKIP INSTRUCTION.	
306	Just to check, are you or your partner doing any of the following to avoid pregnancy: deliberately avoiding sex on certain days, using a condom, using withdrawal or using emergency contraception?	YES . . . . . 1 NO 2

307	Which method are you using? RECORD ALL MENTIONED. IF MORE THAN ONE METHOD MENTIONED, FOLLOW SKIP INSTRUCTION FOR HIGHEST METHOD IN LIST.	FEMALE STERILIZATION . . . . A MALE STERILIZATION . . . . B IUD . . . . C INJECTABLES . . . . D IMPLANTS . . . . E PILL . . . . F MALE CONDOM . . . . G FEMALE CONDOM . . . . H EMERGENCY CONTRACEPTION . . . . I STANDARD DAYS METHOD . . . . J LACTATIONAL AMENORRHEA METHOD . . K RHYTHM METHOD . . . . L WITHDRAWAL . . . . M OTHER MODERN METHOD . . . . X OTHER TRADITIONAL METHOD . . . . Y

G: MARITAL STATUS

701	Now I would like to talk about marriage. Are you currently married or living together with a man as if married?	YES, CURRENTLY MARRIED . . . . 1 YES, LIVING WITH A MAN . . . . 2 NO, NOT IN UNION 3
702	Have you ever been married or lived together with a man as if married?	YES, PREVIOUSLY MARRIED . . . . 1 YES, LIVED WITH A MAN . . . . 2 NO 3
703	What is your marital status now: are you widowed, divorced, or separated?	WIDOWED . . . . 1 DIVORCED . . . . 2 SEPARATED 3

H: EMPLOYMENT STATUS

909	Aside from your own housework, have you done any work in the last 7 days?	YES . . . . 1 NO 2
910	As you know, some women take up jobs for which they are paid in cash or kind. Others sell things, have a small business or work on the family farm or in the family business. In the last 7 days, have you done any of these things or any other work?	YES . . . . 1 NO 2
911	Although you did not work in the last 7 days, do you have any job or business from which you were absent for leave, illness, vacation, maternity leave, or any other such reason?	YES . . . . 1 NO 2

912	Have you done any work in the last 12 months?	YES . . . 1 NO . . . 2
913	What is your occupation? That is, what kind of work do you mainly do?	
914	Do you do this work for a member of your family, for someone else, or are you self-employed?	FOR FAMILY MEMBER . . . 1 FOR SOMEONE ELSE . . . 2 SELF-EMPLOYED . . . 3
915	Do you usually work throughout the year, or do you work seasonally, or only once in a while?	THROUGHOUT THE YEAR . . . 1 SEASONALLY/PART OF THE YEAR . . . 2 ONCE IN A WHILE . . . 3
916	Are you paid in cash or kind for this work or are you not paid at all?	CASH ONLY . . . 1 CASH AND KIND . . . 2 IN KIND ONLY . . . 3 NOT PAID . . . 4

2022 KENYA DEMOGRAPHIC HEALTH SURVEY (KDHS) HOUSEHOLD QUESTIONNAIRE WITH VARIABLES OF INTEREST

I: WEALTH INDEX

101	What is the main source of drinking water for members of your household?	**PIPED WATER** PIPED INTO DWELLING . . . 11 PIPED TO YARD/PLOT . . . 12 PIPED TO NEIGHBOR . . . 13 PUBLIC TAP/STANDPIPE . . . 14 TUBE WELL OR BOREHOLE . . . 21 **DUG WELL** PROTECTED WELL . . . 31 UNPROTECTED WELL . . . 32 **WATER FROM SPRING** PROTECTED SPRING . . . 41 UNPROTECTED SPRING . . . 42 RAINWATER . . . 51 TANKER TRUCK . . . 61 CART WITH SMALL TANK . . . 71 SURFACE WATER (RIVER/DAM/ LAKE/POND/STREAM/CANAL/ IRRIGATION CHANNEL) . . . 81 BOTTLED WATER . . . 91 OTHER ______ 96 (SPECIFY)

102	What is the main source of water used by your household for other purposes such as cooking and handwashing?	**PIPED WATER** PIPED INTO DWELLING . . . . 11 PIPED TO YARD/PLOT . . . . 12 PIPED TO NEIGHBOR . . . . 13 PUBLIC TAP/STANDPIPE . . . . 14 TUBE WELL OR BOREHOLE . . . . 21 **DUG WELL** PROTECTED WELL . . . . 31 UNPROTECTED WELL . . . . 32 **WATER FROM SPRING** PROTECTED SPRING . . . . 41 UNPROTECTED SPRING . . . . 42 RAINWATER . . . . 51 TANKER TRUCK . . . . 61 CART WITH SMALL TANK . . . . 71 SURFACE WATER (RIVER/DAM/ LAKE/POND/STREAM/CANAL/ IRRIGATION CHANNEL) . . . . 81 OTHER ______________ 96 (SPECIFY)
109	What kind of toilet facility do members of your household usually use? IF NOT POSSIBLE TO DETERMINE, ASK PERMISSION TO OBSERVE THE FACILITY.	**FLUSH OR POUR FLUSH TOILET** FLUSH TO PIPED SEWER SYSTEM . . . . 11 FLUSH TO SEPTIC TANK 12 FLUSH TO PIT LATRINE . . . . 13 FLUSH TO SOMEWHERE ELSE . . . . 14 FLUSH, DON'T KNOW WHERE . . . . 15 **PIT LATRINE** VENTILATED IMPROVED PIT LATRINE . . . . 21 PIT LATRINE WITH SLAB . . . . 22 PIT LATRINE WITHOUT SLAB/OPEN PIT . . 23 COMPOSTING TOILET . . . . 31 BIODIGESTER . . . . 32 BUCKET TOILET . . . . 41 HANGING TOILET/HANGING LATRINE . . . . 51 NO FACILITY/BUSH/FIELD . . . . # OTHER ______________ 96 (SPECIFY)
110	Do you share this toilet facility with other households?	YES . . . . 1 NO 2
111	Including your own household, how many households use this toilet facility?	NO. OF HOUSEHOLDS IF LESS THAN 10 . . . . | 0 | | 10 OR MORE HOUSEHOLDS . . . . 95 DON'T KNOW 98
112	Where is this toilet facility located?	IN OWN DWELLING . . . . 1 IN OWN YARD/PLOT . . . . 2 ELSEWHERE 3

			YES	NO
132	Does your household have:		YES	NO
	a) Electricity?	a) ELECTRICITY	1	2
	b) A radio?	b) RADIO	1	2
	c) A television?	c) TELEVISION	1	2
	d) A non-mobile telephone?	d) NON-MOBILE TELEPHONE ..	1	2
	e) A computer?	e) COMPUTER	1	2
	f) A refrigerator?	f) REFRIGERATOR	1	2
	g) A solar panel?	g) SOLAR PANEL	1	2
	h) A table?	h) TABLE	1	2
	i) A chair?	i) CHAIR	1	2
	j) A sofa?	j) SOFA ..	1	2
	k) A bed?	k) BED	1	2
	l) A cupboard?	l) CUPBOARD	1	2
	m) A clock?	m) CLOCK ..	1	2
	n) A microwave oven?	n) MICROWAVE OVEN	1	2
	o) A DVD player?	o) DVD PLAYER	1	2
	p) A cassette or CD player?	p) CASSETTE/CD PLAYE..........	1	2

			YES	NO
133	Does any member of this household own:		YES	NO
	a) A watch?	a) WATCH	1	2
	b) A mobile phone?	b) MOBILE PHONE	1	2
	c) A bicycle?	c) BICYCLE	1	2
	d) A motorcycle or motor scooter?	d) MOTORCYCLE/SCOOTER	1	2
	e) An animal-drawn cart?	e) ANIMAL-DRAWN CART	1	2
	f) A car or truck?	f) CAR/TRUCK	1	2
	g) A boat with a motor?	g) BOAT WITH MOTOR	1	2

152	OBSERVE MAIN MATERIAL OF THE FLOOR OF THE DWELLING. RECORD OBSERVATION.	**NATURAL FLOOR**	
		EARTH/SAND	11
		DUNG	12
		RUDIMENTARY FLOOR	
		WOOD PLANKS	21
		PALM/BAMBOO	22
		FINISHED FLOOR	
		PARQUET OR POLISHED WOOD	31
		VINYL OR ASPHALT STRIPS	32
		CERAMIC TILES	33
		CEMENT	34
		CARPET	35
		OTHER ______________________ (SPECIFY)	96

153	OBSERVE MAIN MATERIAL OF THE ROOF OF THE DWELLING. RECORD OBSERVATION.	**NATURAL ROOFING**	
		NO ROOF	11
		THATCH/GRASS/MAKUTI	12
		SOD/MUD/DUNG	13
		RUDIMENTARY ROOFING	
		RUSTIC MAT	21
		PALM/BAMBOO	22
		WOOD PLANKS	23
		CARDBOARD	24
		TIN CANS	25
		FINISHED ROOFING	
		IRON SHEETS/METAL	31
		WOOD	32
		CALAMINE/CEMENT FIBER	33
		CERAMIC TILES	34
		CEMENT	35
		ROOFING SHINGLES	36
		ASBESTOS SHEET	37
		OTHER ______________________ (SPECIFY)	96

154	OBSERVE MAIN MATERIAL OF THE EXTERIOR WALLS OF THE DWELLING. RECORD OBSERVATION.	**NATURAL WALLS** NO WALLS . . . . 11 CANE/PALM/TRUNKS . . . . 12 DIRT . . . . 13 **RUDIMENTARY WALLS** BAMBOO WITH MUD . . . . 21 STONE WITH MUD . . . . 22 UNCOVERED ADOBE . . . . 23 PLYWOOD . . . . 24 CARDBOARD . . . . 25 REUSED WOOD . . . . 26 IRON SHEETS . . . . 27 **FINISHED WALLS** CEMENT . . . . 31 STONE WITH LIME/CEMENT . . . . 32 BRICKS . . . . 33 CEMENT BLOCKS . . . . 34 COVERED ADOBE . . . . 35 WOOD PLANKS/SHINGLES . . . . 36 OTHER ______________________ 96 (SPECIFY)	

KNH-UoN Ethical Approval Letter

UNIVERSITY OF NAIROBI
FACULTY OF HEALTH SCIENCES
P O BOX 19676 Code 00202
TELEGRAMS: varsity
Tel:(254-020) 2726300 Ext 44355

KENYATTA NATIONAL HOSPITAL APPROVED 28 SEP 2023 KNH/UoN-ERC P.O. Box 20723-00202 NAIROBI

KNH-UON ERC
Email: uonknh_erc@uonbi.ac.ke
Website: http://www.erc.uonbi.ac.ke
Facebook: https://www.facebook.com/uonknh.erc
Twitter: @UONKNH_ERC https://twitter.com/UONKNH_ERC

KENYATTA NATIONAL HOSPITAL
P O BOX 20723 Code 00202
Tel: 726300-9
Fax: 725272
Telegrams: MEDSUP, Nairobi

Ref: KNH-ERC/A/490

28th September, 2023

Peninah Wangari Muigai
Reg. No. W62/34448/2019
Dept. of Public & Global Health
Faculty of Health Sciences
University of Nairobi

Dear Peninah,

ETHICAL APPROVAL-RESEARCH PROPOSAL: SPATIAL ANALYSIS OF MODERN CONTRACEPTIVE USE AMONGST WOMEN OF CHILDBEARING AGE IN KENYA (P540/06/2023)

This is to inform you that KNH-UoN ERC has reviewed and approved your above research proposal. Your application approval number is **P540/06/2023.** The approval period is 28th September 2023 –27th September 2024.

This approval is subject to compliance with the following requirements:

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by KNH-UoN ERC.
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to KNH-UoN ERC 72 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH-UoN ERC within 72 hours.
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to KNH-UoN ERC.

Protect to discover

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://research-portal.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely,

PROF. BEATRICE K.M. AMUGUNE
SECRETARY, KNH- UoN ERC

c.c. The Dean, Faculty of Health Sciences, UoN
The Senior Director, CS, KNH
The Chairperson, KNH- UoN ERC
The Assistant Director, Health Information Dept., KNH
The Chair, Dept. of Public & Global Health, UoN
Supervisor: Dr. Isaac C Kipchirchir, Dept. of Mathematics, UoN
Dr. Peter Cherutich, Dept. of Public & Global Health, UoN.

9/11/2023

Turnitin report

Spatial Analysis Of Modern Contraceptive Use Amongst Women Of Childbearing Age In Kenya

ORIGINALITY REPORT

15%	8%	11%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.ncbi.nlm.nih.gov Internet Source	2%
2	Girma Gilano, Samuel Hailegebreal. "Assessment of intention to use contraceptive methods with spatial distributions and associated factors among women in Ethiopia: evidence from EDHS 2016", Archives of Public Health, 2021 Publication	1%
3	Chinelo Okigbo, Ilene Speizer, Marisa Domino, Sian Curtis. "A Multilevel Logit Estimation of Factors Associated With Modern Contraception in Urban Nigeria", World Medical & Health Policy, 2017 Publication	1%
4	dsgocdnapi.azureedge.net Internet Source	<1%
5	Pingping Ma, Yan Song, Ming Zhang. "Mediating and spatial spillover effects of public participation in environmental pollution	<1%

Description of the study variables

Table 7. Description of the study variables

Variable	**Variable description**
Dependent variable	
Status of modern contraceptive use	Modern method = 1, then otherwise 0 for any other method that is not modern.
Independent variables	
Individual characteristics	
Employment status	Currently working = 1 Currently not working = 0
Level of education (Reference = no education)	Suppose Primary = 1, then otherwise 0 for secondary or higher. Secondary = 1, then otherwise 0 for primary or higher. Higher = 1, then otherwise 0 for primary or secondary.
Age	Measured as a discrete variable.
Parity	A discrete variable measured as the total number of children ever born.
Religion (Reference = other)	Catholic = 1, then otherwise 0 for Protestant, Evangelical churches, African instituted churches, Islam, Atheists, Combined religion. Protestant = 1, then otherwise 0 for Catholic, Evangelical churches, African instituted churches, Islam, Atheists, Combined religion. Evangelical churches =1, then otherwise 0 for Protestant, Catholic, African instituted churches, Islam, Atheists, Combined religion.

	African instituted churches = 1, then otherwise 0 for Protestant, Evangelical churches, Catholic, Islam, Atheists, Combined religion. Islam = 1, then otherwise 0 for Protestant, Evangelical churches, African instituted churches, Catholic, Atheists, Combined religion. Atheists = 1, then otherwise 0 for Protestant, Evangelical churches, African instituted churches, Islam, Catholic, Combined religion. Combined religion = 1, then otherwise 0 for Protestant, Evangelical churches, African instituted churches, Islam, Atheists, Catholic.
Marital status (Reference = never in union)	Suppose Married = 1, then otherwise 0 for Living with partner, Widowed, Divorced, Separated. Suppose Living with partner = 1, then otherwise 0 for Married, Widowed, Divorced, Separated. Suppose Widowed = 1, then otherwise 0 for Living with partner, Married, Divorced, Separated.

	Suppose Divorced = 1, then otherwise 0 for Living with partner, Widowed, Married, Separated. Suppose Separated = 1, then otherwise 0 for Living with partner, Widowed, Divorced, Married.
Household characteristics	
Wealth index (Reference = poorest)	Suppose Poor = 1, then otherwise 0 for Middle, Richer, Richer, Richest. Middle = 1, then otherwise 0 for Poor, Richer, Richer, Richest. Richer = 1, then otherwise 0 for Middle, Richer, Poor, Richest. Richest = 1, then otherwise 0 for Middle, Richer, Richer, Poor.
Residence	Urban = 1 Rural = 0
Spatial characteristics	
County	Mombasa, Kwale, Kilifi, Tana river, Lamu,Taita Taveta, Garissa, Wajir,Mandera, Marsabit, Isiolo, Meru, Tharaka-nithi, Embu, Kitui, Machakos, Makueni, Nyandarua, Nyeri, Kirinyaga, Murang'a, Kiambu, Turkana, West Pokot, Samburu, Trans-nzoia, Uasin Gishu, Elgeyo Marakwet, Nandi, Baringo, Laikipia, Nakuru, Narok, Kajiado, Kericho, Bomet, Kakamega, Vihiga, Bungoma, Busia, Siaya, Kisumu, Homa Bay, Migori, Kisii, Nyamira, Nairobi

WinBUGS codes

#Objective one analysis

```
model
{
#likelihood
for(i in 1: N)
{
modern[i]~dbern(p[i])
p[i]<-min(1,max(0,pmodern[i]))

#weighted likelihood
pw[i]<-pmodern[i]*weight[i]

A[i]<-
beta0+beta1*age[i]+beta2*catholic[i]+beta3*protestant[i]+beta4*evangelical_churches[i]+beta5
*african_instituted_churches[i]+beta6*islam[i]+beta7*atheists[i]+beta8*combinedreligion[i]

B[i]<-
beta9*married[i]+beta10*living_with_partner[i]+beta11*widowed[i]+beta12*divorced[i]+beta1
3*separated[i]

C[i]<-
beta14*poorer[i]+beta15*middle[i]+beta16*richer[i]+beta17*richest[i]+beta18*employment_sta
tus[i]+beta19*primary[i]+beta20*secondary[i]+beta21*higher[i]+beta22*residence[i]+beta23*p
arity[i]

logit(pmodern[i])<-A[i]+B[i]+C[i]
}

#priors
beta0~dnorm(0.0001,0.0001)
beta1~dnorm(0.0001,0.001)
beta2~dnorm(0.0001,0.0001)
beta3~dnorm(0.0001,0.0001)
beta4~dnorm(0.0001,0.0001)
beta5~dnorm(0.0001,0.0001)
beta6~dnorm(0.0001,0.001)
beta7~dnorm(0.0001,0.0001)
beta8~dnorm(0.0001,0.0001)
beta9~dnorm(0.0001,0.0001)
beta10~dnorm(0.0001,0.0001)
beta11~dnorm(0.0001,0.001)
beta12~dnorm(0.0001,0.0001)
beta13~dnorm(0.0001,0.0001)
beta14~dnorm(0.0001,0.0001)
```

```
beta15~dnorm(0.0001,0.0001)
beta16~dnorm(0.0001,0.001)
beta17~dnorm(0.0001,0.0001)
beta18~dnorm(0.0001,0.0001)
beta19~dnorm(0.0001,0.0001)
beta20~dnorm(0.0001,0.0001)
beta21~dnorm(0.0001,0.001)
beta22~dnorm(0.0001,0.0001)
beta23~dnorm(0.0001,0.0001)
}

#initials
list(beta0=0,beta1=0,beta2=0,beta3=0,beta4=0,beta5=0,beta6=0,beta7=0,beta8=0,beta9=0,beta10=0,beta11=0,beta12=0,beta13=0,beta14=0,beta15=0,beta16=0,beta17=0,beta18=0,beta19=0,beta20=0,beta21=0,beta22=0,beta23=0)


#data

list(N=32156,age=c(34,38,33….35),catholic=c(1,0,0,…,1),protestant=c(1,0,1,…,1),evangelical_churches=c(0,0,1,…,1),african_instituted_churches=c(1,0,1,…,1),islam=c(0,0,1,…,0),atheists=c(1,1,0,…,0),combinedreligion=c(1,1,1,…,0),married=c(1,0,1,…,1),living_with_partner=c(0,0,1,…,1),widowed=c(0,1,0,…1),divorced=(0,0,1,…,1),separated=c(1,1,0,…,0),poorer=c(0,0,1,…,0),middle=c(1,0,1,…,0),richer=c(0,0,1,…,1),richest=c(0,1,0,…,1),employment_status=c(1,0,1,…,1),primary=c(0,1,1,…,0),secondary=c(1,0,1,…,1),higher=c(0,0,1,…,1),residence=c(1,0,1,…,1),parity=c(4,3,1,…,2),weight=c(1.296049,1.296049,1.296049,…,8.074191))
```

#Objective two analysis

```
model
{
#likelihood
for(i in 1: N)
{
modern[i]~dbern(p[i])
p[i]<-min(1,max(0,pmodern[i]))

#weighted likelihood
pw[i]<-pmodern[i]*weight[i]

A[i]<-
beta0+beta1*age[i]+beta2*catholic[i]+beta3*protestant[i]+beta4*evangelical_churches[i]+beta5*african_instituted_churches[i]+beta6*islam[i]+beta7*atheists[i]+beta8*combinedreligion[i]
```

```
B[i]<-
beta9*married[i]+beta10*living_with_partner[i]+beta11*widowed[i]+beta12*divorced[i]+beta1
3*separated[i]

C[i]<-
beta14*poorer[i]+beta15*middle[i]+beta16*richer[i]+beta17*richest[i]+beta18*employment_sta
tus[i]+beta19*primary[i]+beta20*secondary[i]+beta21*higher[i]+beta22*residence[i]+beta23*p
arity[i]+v[county[i]]

logit(pmodern[i])<-A[i]+B[i]+C[i]
}

#Random effects
# M is number of counties
for (j in 1:M) {

v[j]~dnorm(0, tau) #non informative prior for random effect
}

# fixed effects priors
beta0~dnorm(0.0001,0.0001)
beta1~dnorm(0.0001,0.001)
beta2~dnorm(0.0001,0.0001)
beta3~dnorm(0.0001,0.0001)
beta4~dnorm(0.0001,0.0001)
beta5~dnorm(0.0001,0.0001)
beta6~dnorm(0.0001,0.001)
beta7~dnorm(0.0001,0.0001)
beta8~dnorm(0.0001,0.0001)
beta9~dnorm(0.0001,0.0001)
beta10~dnorm(0.0001,0.0001)
beta11~dnorm(0.0001,0.001)
beta12~dnorm(0.0001,0.0001)
beta13~dnorm(0.0001,0.0001)
beta14~dnorm(0.0001,0.0001)
beta15~dnorm(0.0001,0.0001)
beta16~dnorm(0.0001,0.001)
beta17~dnorm(0.0001,0.0001)
beta18~dnorm(0.0001,0.0001)
beta19~dnorm(0.0001,0.0001)
beta20~dnorm(0.0001,0.0001)
beta21~dnorm(0.0001,0.001)
beta22~dnorm(0.0001,0.0001)
beta23~dnorm(0.0001,0.0001)
```

#Hyperprior for random effect precision

tau~dgamma(0.001, 0.001)

}

#initials
list(beta0=0,beta1=0,beta2=0,beta3=0,beta4=0,beta5=0,beta6=0,beta7=0,beta8=0,beta9=0,beta10=0,beta11=0,beta12=0,beta13=0,beta14=0,beta15=0,beta16=0,beta17=0,beta18=0,beta19=0,beta20=0,beta21=0,beta22=0,beta23=0,tau=1,v=c(0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0))

#data
list(N=32156,M=47, age=c(34,38,33….35),
catholic=c(1,0,0,…,1),protestant=c(1,0,1,…,1),evangelical_churches=c(0,0,1,…,1),african_instituted_churches=c(1,0,1,…,1),islam
=c(0,0,1,…,0),atheists=c(1,1,0,…,0),combinedreligion=c(1,1,1,…,0),married=c(1,0,1,…,1),living_with_partner=c(0,0,1,…,1),widowed=c(0,1,0,…1),divorced=(0,0,1,…,1),separated=c(1,1,0,…,0),poorer=c(0,0,1,…,0),middle=c(1,0,1,…,0),richer=c(0,0,1,…,1),richest=c(0,1,0,…,1),employment_status=c(1,0,1,…,1),primary=c(0,1,1,…,0),secondary=c(1,0,1,…,1),higher=c(0,0,1,…,1),residence=c(1,0,1,…,1),parity=c(4,3,1,…,2),county=47,47,47,…,23),weight=c(1.296049,1.296049,1.296049,…,8.074191))

#Objective three analysis

```
model
{
#likelihood
for(i in 1: N)
{
modern[i]~dbern(p[i])
p[i]<-min(1,max(0,pmodern[i]))

#weighted likelihood
pw[i]<-pmodern[i]*weight[i]

A[i]<-
beta0+beta1*age[i]+beta2*catholic[i]+beta3*protestant[i]+beta4*evangelical_churches[i]+beta5*african_instituted_churches[i]+beta6*islam[i]+beta7*atheists[i]+beta8*combinedreligion[i]


B[i]<-
beta9*married[i]+beta10*living_with_partner[i]+beta11*widowed[i]+beta12*divorced[i]+beta13*separated[i]
```

```
C[i]<-
beta14*poorer[i]+beta15*middle[i]+beta16*richer[i]+beta17*richest[i]+beta18*employment_sta
tus[i]+beta19*primary[i]+beta20*secondary[i]+beta21*higher[i]+beta22*residence[i]+beta23*p
arity[i]+U[county[i]]

logit(pmodern[i])<-A[i]+B[i]+C[i]
}

# fixed effects priors
beta0~dnorm(0.0001,0.0001)
beta1~dnorm(0.0001,0.001)
beta2~dnorm(0.0001,0.0001)
beta3~dnorm(0.0001,0.0001)
beta4~dnorm(0.0001,0.0001)
beta5~dnorm(0.0001,0.0001)
beta6~dnorm(0.0001,0.001)
beta7~dnorm(0.0001,0.0001)
beta8~dnorm(0.0001,0.0001)
beta9~dnorm(0.0001,0.0001)
beta10~dnorm(0.0001,0.0001)
beta11~dnorm(0.0001,0.001)
beta12~dnorm(0.0001,0.0001)
beta13~dnorm(0.0001,0.0001)
beta14~dnorm(0.0001,0.0001)
beta15~dnorm(0.0001,0.0001)
beta16~dnorm(0.0001,0.001)
beta17~dnorm(0.0001,0.0001)
beta18~dnorm(0.0001,0.0001)
beta19~dnorm(0.0001,0.0001)
beta20~dnorm(0.0001,0.0001)
beta21~dnorm(0.0001,0.001)
beta22~dnorm(0.0001,0.0001)
beta23~dnorm(0.0001,0.0001)

#Hyperprior for random effect  precision

omega.spatial~dgamma(0.5,0.005)

omega.spatialsq<-1/omega.spatial

U[1:M] ~ car.normal(adj[], weights[], num[], omega.spatial)

for (k in 1:sumNumNeigh) {
        weights[k] <- 1
      }
for(i in 1:N)
```

```
    {
                    for(j in 1: M)
                            {
                                PM[j,i]<-(pmodern[i]*(equals(county[i],j)))
                            }
                }
for(j in 1:M)
    {
                        for(i in 1: N)
                                {
                                    count[j,i]<-equals(county[i],j)
                                }

                number[j]<-sum(count[j,])
                    PCM[j]<-sum(PM[j,])/number[j]
                    }
}

#initials
list(beta0=0,beta1=0,beta2=0,beta3=0,beta4=0,beta5=0,beta6=0,beta7=0,beta8=0,beta9=0,beta1
0=0,beta11=0,beta12=0,beta13=0,beta14=0,beta15=0,beta16=0,beta17=0,beta18=0,beta19=0,bet
a20=0,beta21=0,beta22=0,beta23=0,omega.spatial=0.01,U=c(0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0))

#data
list( N=32156,num = c(4, 4, 1, 4, 4, 5, 8, 8, 4, 5,
3, 3, 6, 7, 7, 3, 7, 5, 5, 8,
4, 5, 5, 8, 5, 7, 4, 8, 6, 7,
6, 5, 5, 6, 5, 6, 3, 6, 8, 7,
3, 4, 0, 2, 4, 2, 2
),
adj = c(
8, 6, 5, 2,
7, 6, 4, 1,
4,
12, 7, 3, 2,
10, 9, 8, 1,
15, 8, 7, 2, 1,
28, 27, 17, 15, 12, 6, 4, 2,
24, 20, 15, 13, 9, 6, 5, 1,
13, 10, 8, 5,
14, 13, 11, 9, 5,
16, 14, 10,
27, 7, 4,
24, 18, 14, 10, 9, 8,
21, 19, 18, 16, 13, 11, 10,
```

```
26, 22, 20, 17, 8, 7, 6,
19, 14, 11,
30, 29, 28, 26, 23, 15, 7,
25, 24, 21, 14, 13,
31, 25, 21, 16, 14,
40, 38, 34, 32, 24, 22, 15, 8,
25, 19, 18, 14,
38, 36, 26, 20, 15,
30, 29, 28, 26, 17,
33, 32, 31, 25, 20, 18, 13, 8,
31, 24, 21, 19, 18,
36, 30, 29, 23, 22, 17, 15,
45, 28, 12, 7,
45, 42, 39, 30, 27, 23, 17, 7,
39, 36, 30, 26, 23, 17,
39, 36, 29, 28, 26, 23, 17,
37, 35, 33, 25, 24, 19,
35, 34, 33, 24, 20,
35, 34, 32, 31, 24,
40, 37, 35, 33, 32, 20,
37, 34, 33, 32, 31,
39, 38, 30, 29, 26, 22,
35, 34, 31,
41, 40, 39, 36, 22, 20,
42, 41, 40, 38, 36, 30, 29, 28,
45, 42, 41, 39, 38, 34, 20,
40, 39, 38,
45, 40, 39, 28,
47, 46,
42, 40, 28, 27,
47, 44,
46, 44
),
sumNumNeigh = 234,
age=c(34,38,33….35),
catholic=c(1,0,0,…,1),protestant=c(1,0,1,…,1),evangelical_churches=c(0,0,1,…,1),african_instit
uted_churches=c(1,0,1,…,1),islam
=c(0,0,1,…,0),atheists=c(1,1,0,…,0),combinedreligion=c(1,1,1,…,0),married=c(1,0,1,…,1),livin
g_with_partner=c(0,0,1,…,1),widowed=c(0,1,0,…1),divorced=(0,0,1,…,1),separated=c(1,1,0,…,
0),poorer=c(0,0,1,…,0),middle=c(1,0,1,…,0),richer=c(0,0,1,…,1),richest=c(0,1,0,…,1),employm
ent_status=c(1,0,1,…,1),primary=c(0,1,1,…,0),secondary=c(1,0,1,…,1),higher=c(0,0,1,…,1),resi
dence=c(1,0,1,…,1),parity=c(4,3,1,…,2),county=47,47,47,…,23),weight=c(1.296049,1.296049,1
.296049,…,8.074191))
```

#Objective four analysis

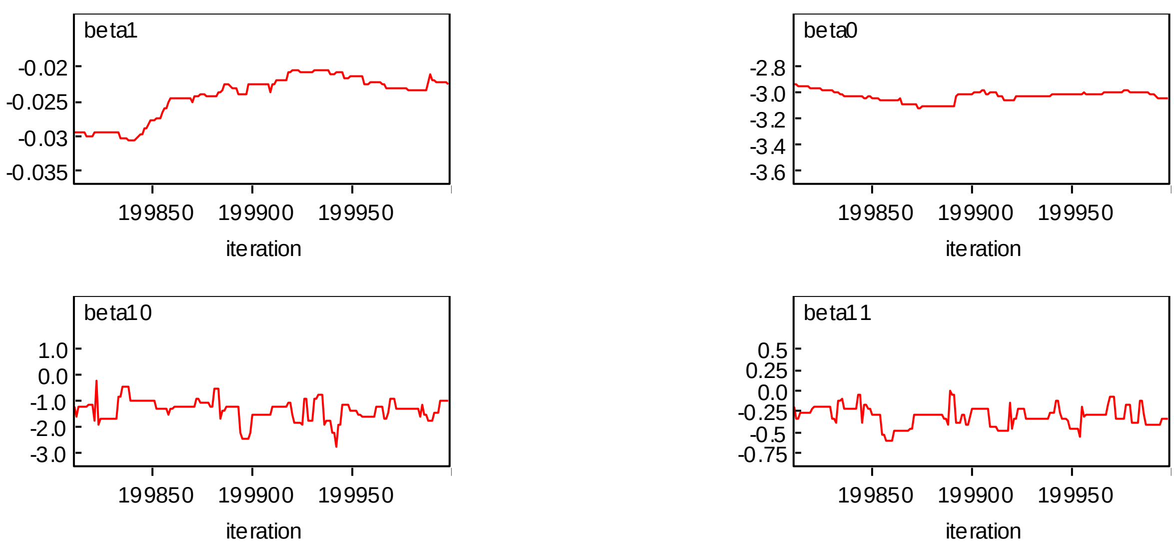
```
model
{
#likelihood
for(i in 1: N)
{
modern[i]~dbern(p[i])
p[i]<-min(1,max(0,pmodern[i]))

A[i]<-
beta0+beta1*age[i]+beta2*catholic[i]+beta3*protestant[i]+beta4*evangelical_churches[i]+beta5
*african_instituted_churches[i]+beta6*islam[i]+beta7*atheists[i]+beta8*combinedreligion[i]


B[i]<-
beta9*married[i]+beta10*living_with_partner[i]+beta11*widowed[i]+beta12*divorced[i]+beta1
3*separated[i]

C[i]<-
beta14*poorer[i]+beta15*middle[i]+beta16*richer[i]+beta17*richest[i]+beta18*employment_sta
tus[i]+beta19*primary[i]+beta20*secondary[i]+beta21*higher[i]+beta22*residence[i]+beta23*p
arity[i]+V[county[i]]+U[county[i]]

logit(pmodern[i])<-A[i]+B[i]+C[i]
}

#Random effects
# M is number of counties
for (j in 1:M) {

V[j]~dnorm(0, omega.v) #non informative prior for random effect
}

# fixed effects priors
beta0~dnorm(0.0001,0.0001)
beta1~dnorm(0.0001,0.001)
beta2~dnorm(0.0001,0.0001)
beta3~dnorm(0.0001,0.0001)
beta4~dnorm(0.0001,0.0001)
beta5~dnorm(0.0001,0.0001)
beta6~dnorm(0.0001,0.001)
beta7~dnorm(0.0001,0.0001)
beta8~dnorm(0.0001,0.0001)
beta9~dnorm(0.0001,0.0001)
beta10~dnorm(0.0001,0.0001)
beta11~dnorm(0.0001,0.001)
beta12~dnorm(0.0001,0.0001)
```

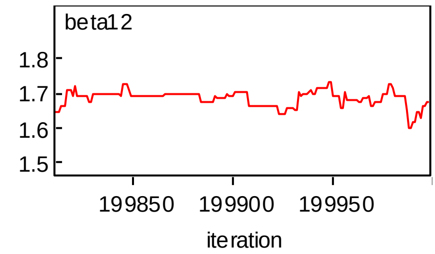
```
beta13~dnorm(0.0001,0.0001)
beta14~dnorm(0.0001,0.0001)
beta15~dnorm(0.0001,0.0001)
beta16~dnorm(0.0001,0.001)
beta17~dnorm(0.0001,0.0001)
beta18~dnorm(0.0001,0.0001)
beta19~dnorm(0.0001,0.0001)
beta20~dnorm(0.0001,0.0001)
beta21~dnorm(0.0001,0.001)
beta22~dnorm(0.0001,0.0001)
beta23~dnorm(0.0001,0.0001)

#Hyperprior for random effect  precision

omega.v~dgamma(0.5, 0.005)
omega.spatial~dgamma(0.5,0.005)

omega.vsq<-1/omega.v
omega.spatialsq<-1/omega.spatial

U[1:M] ~ car.normal(adj[], weights[], num[], omega.spatial)

for (k in 1:sumNumNeigh) {
            weights[k] <- 1
          }
for(i in 1:N)
     {
                              for(j in 1: M)
                                                  {
                                                            PM[j,i]<-(pmodern[i]*(equals(county[i],j)))
                                                  }
                    }
for(j in 1:M)
    {
                                        for(i in 1: N)
                                                            {
                                                                      count[j,i]<-equals(county[i],j)
                                                            }

                    number[j]<-sum(count[j,])
                              PCM[j]<-sum(PM[j,])/number[j]
                              }
}

#initials
```

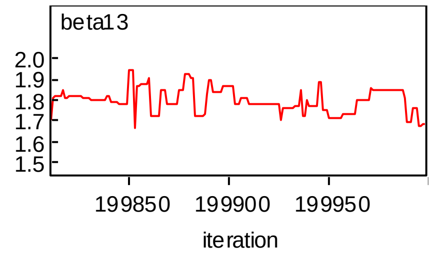
```
list(beta0=0,beta1=0,beta2=0,beta3=0,beta4=0,beta5=0,beta6=0,beta7=0,beta8=0,beta9=0,beta1
0=0,beta11=0,beta12=0,beta13=0,beta14=0,beta15=0,beta16=0,beta17=0,beta18=0,beta19=0,bet
a20=0,beta21=0,beta22=0,beta23=0,omega.v=1,omega.spatial=0.01,V=c(0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0),U=c(0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0))

#data

list( N=32156,M=47,num = c(4, 4, 1, 4, 4, 5, 8, 8, 4, 5,
3, 3, 6, 7, 7, 3, 7, 5, 5, 8,
4, 5, 5, 8, 5, 7, 4, 8, 6, 7,
6, 5, 5, 6, 5, 6, 3, 6, 8, 7,
3, 4, 0, 2, 4, 2, 2
),
adj = c(
8, 6, 5, 2,
7, 6, 4, 1,
4,
12, 7, 3, 2,
10, 9, 8, 1,
15, 8, 7, 2, 1,
28, 27, 17, 15, 12, 6, 4, 2,
24, 20, 15, 13, 9, 6, 5, 1,
13, 10, 8, 5,
14, 13, 11, 9, 5,
16, 14, 10,
27, 7, 4,
24, 18, 14, 10, 9, 8,
21, 19, 18, 16, 13, 11, 10,
26, 22, 20, 17, 8, 7, 6,
19, 14, 11,
30, 29, 28, 26, 23, 15, 7,
25, 24, 21, 14, 13,
31, 25, 21, 16, 14,
40, 38, 34, 32, 24, 22, 15, 8,
25, 19, 18, 14,
38, 36, 26, 20, 15,
30, 29, 28, 26, 17,
33, 32, 31, 25, 20, 18, 13, 8,
31, 24, 21, 19, 18,
36, 30, 29, 23, 22, 17, 15,
45, 28, 12, 7,
45, 42, 39, 30, 27, 23, 17, 7,
39, 36, 30, 26, 23, 17,
39, 36, 29, 28, 26, 23, 17,
37, 35, 33, 25, 24, 19,
```

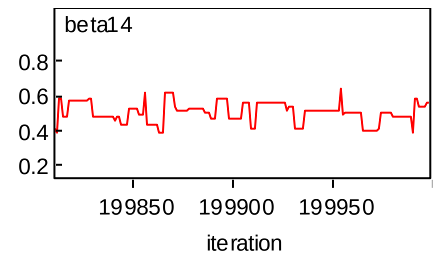
35, 34, 33, 24, 20,
35, 34, 32, 31, 24,
40, 37, 35, 33, 32, 20,
37, 34, 33, 32, 31,
39, 38, 30, 29, 26, 22,
35, 34, 31,
41, 40, 39, 36, 22, 20,
42, 41, 40, 38, 36, 30, 29, 28,
45, 42, 41, 39, 38, 34, 20,
40, 39, 38,
45, 40, 39, 28,
47, 46,
42, 40, 28, 27,
47, 44,
46, 44
),
sumNumNeigh = 234,
age=c(34,38,33….35),
catholic=c(1,0,0,…,1),protestant=c(1,0,1,…,1),evangelical_churches=c(0,0,1,…,1),african_instituted_churches=c(1,0,1,…,1),islam
=c(0,0,1,…,0),atheists=c(1,1,0,…,0),combinedreligion=c(1,1,1,…,0),married=c(1,0,1,…,1),living_with_partner=c(0,0,1,…,1),widowed=c(0,1,0,…1),divorced=(0,0,1,…,1),separated=c(1,1,0,…,0),poorer=c(0,0,1,…,0),middle=c(1,0,1,…,0),richer=c(0,0,1,…,1),richest=c(0,1,0,…,1),employment_status=c(1,0,1,…,1),primary=c(0,1,1,…,0),secondary=c(1,0,1,…,1),higher=c(0,0,1,…,1),residence=c(1,0,1,…,1),parity=c(4,3,1,…,2),county=47,47,47,…,23),weight=c(1.296049,1.296049,1.296049,…,8.074191))

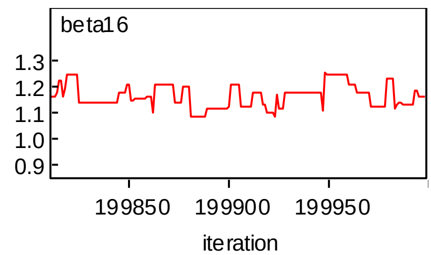
Trace plots MCMC algorithm (convergence)

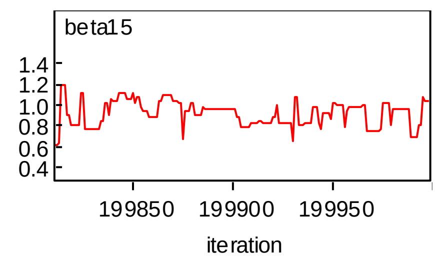


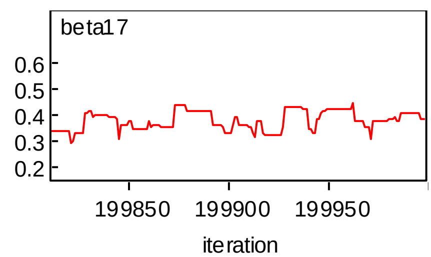

beta12
1.8
1.7
1.6
1.5
199850
199900
199950
iteration

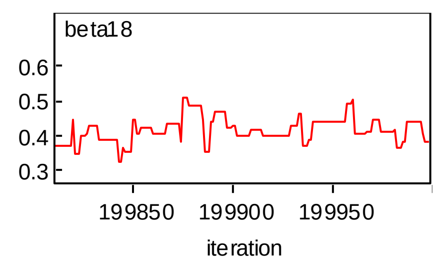

beta13
2.0
1.9
1.8
1.7
1.6
1.5
199850
199900
199950
iteration

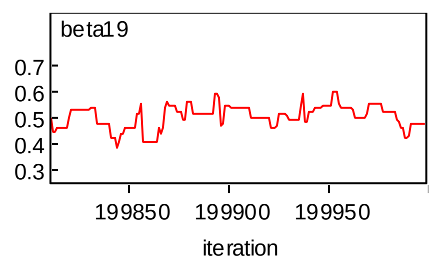

beta14
0.8
0.6
0.4
0.2
199850
199900
199950
iteration

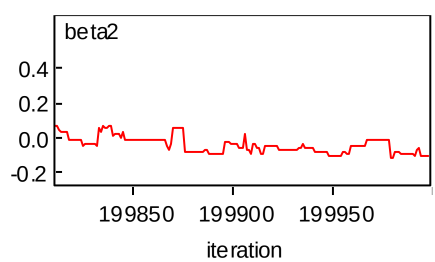

beta16
1.3
1.2
1.1
1.0
0.9
199850
199900
199950
iteration

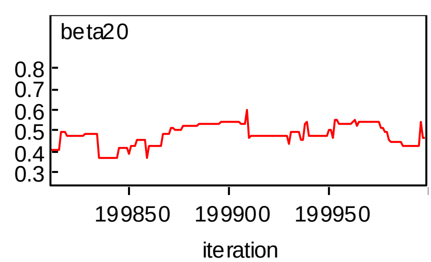

beta15
1.4
1.2
1.0
0.8
0.6
0.4
199850
199900
199950
iteration

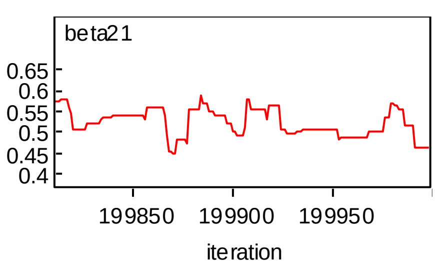

beta17
0.6
0.5
0.4
0.3
0.2
199850
199900
199950
iteration

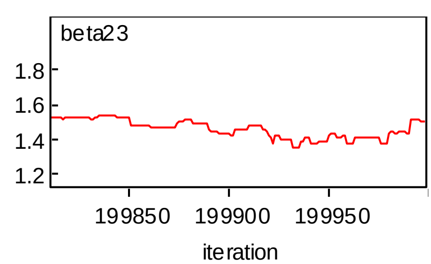

beta18
0.6
0.5
0.4
0.3
199850
199900
199950
iteration

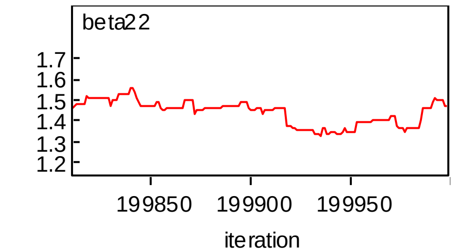

beta19
0.7
0.6
0.5
0.4
0.3
199850
199900
199950
iteration

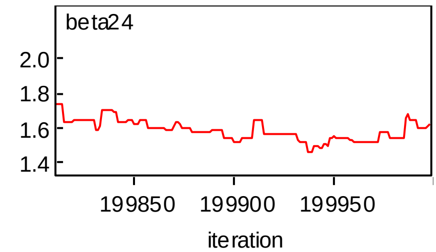

beta2
0.4
0.2
0.0
-0.2
199850
199900
199950
iteration

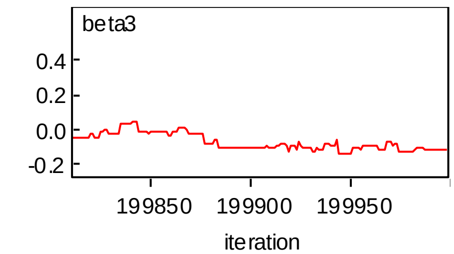

beta20
0.8
0.7
0.6
0.5
0.4
0.3
199850
199900
199950
iteration

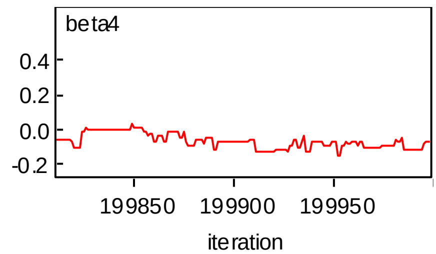

beta21
0.65
0.6
0.55
0.5
0.45
0.4
199850
199900
199950
iteration

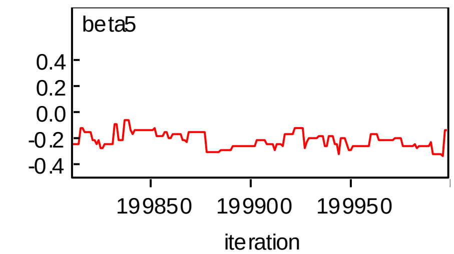

beta23
1.8
1.6
1.4
1.2
199850
199900
199950
iteration

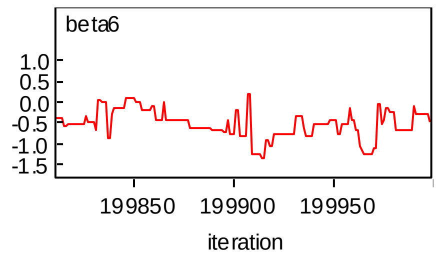

beta22
1.7
1.6
1.5
1.4
1.3
1.2
199850
199900
199950
iteration

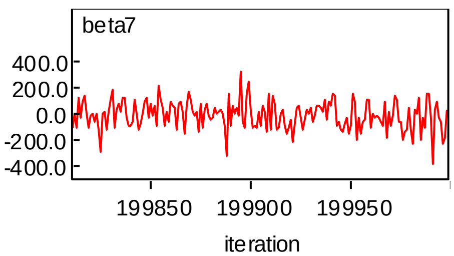

beta24
2.0
1.8
1.6
1.4
199850
199900
199950
iteration

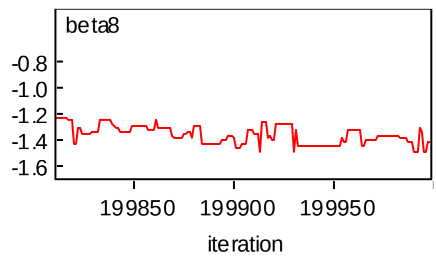

beta3
0.4
0.2
0.0
-0.2
199850
199900
199950
iteration

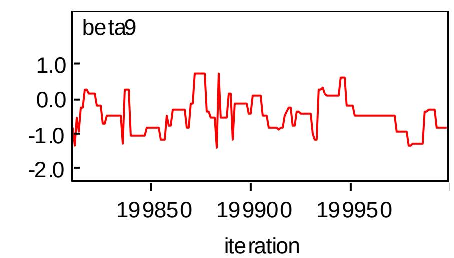

beta4
0.4
0.2
0.0
-0.2
199850
199900
199950
iteration

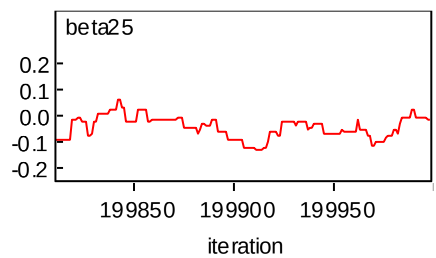

beta5
0.4
0.2
0.0
-0.2
-0.4
199850
199900
199950
iteration


beta6
1.0
0.5
0.0
-0.5
-1.0
-1.5
199850
199900
199950
iteration


beta7
400.0
200.0
0.0
-200.0
-400.0
199850
199900
199950
iteration


beta8
-0.8
-1.0
-1.2
-1.4
-1.6
199850
199900
199950
iteration


beta9
1.0
0.0
-1.0
-2.0
199850
199900
199950
iteration


beta25
0.2
0.1
0.0
-0.1
-0.2
199850
199900
199950
iteration

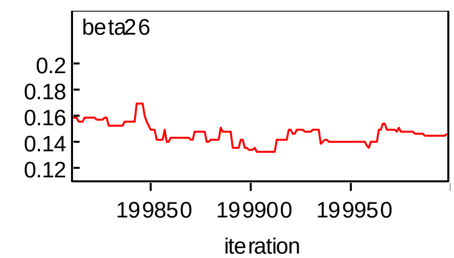
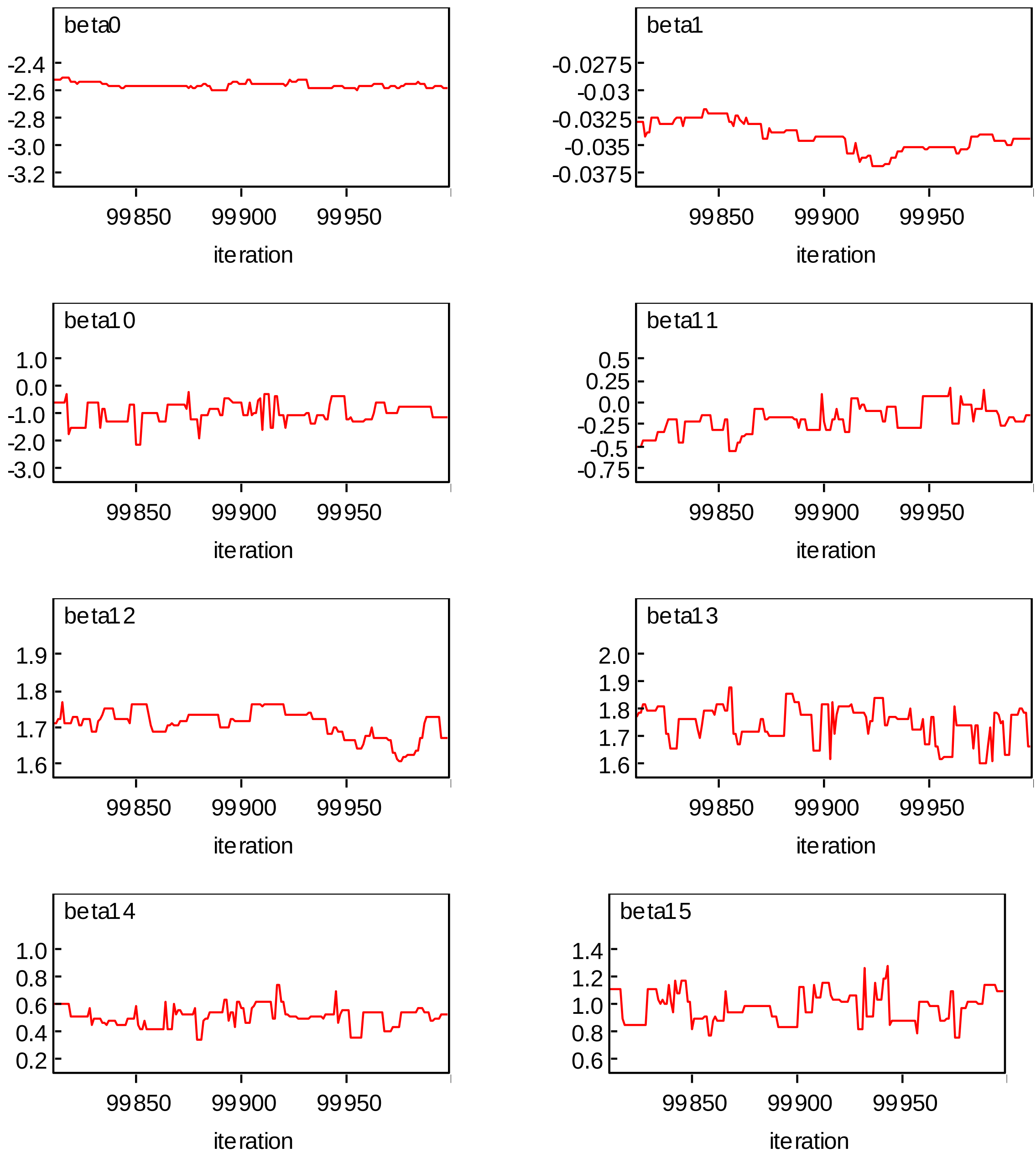
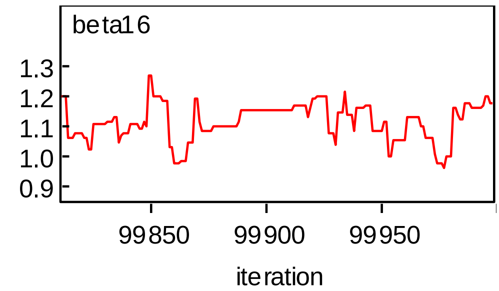
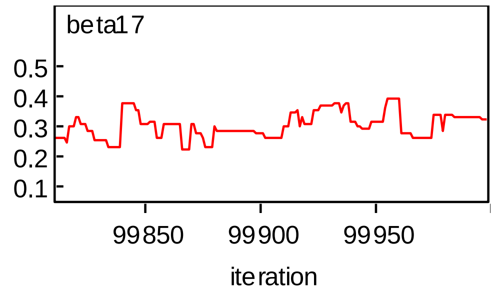
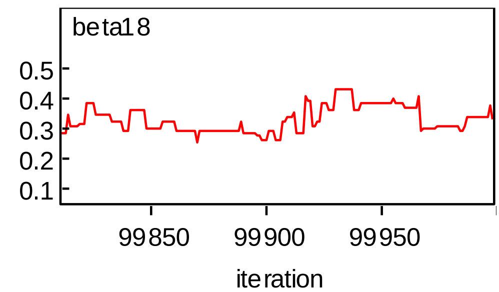
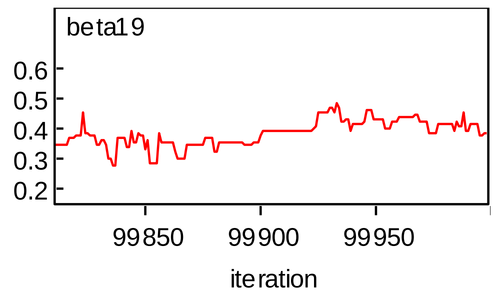
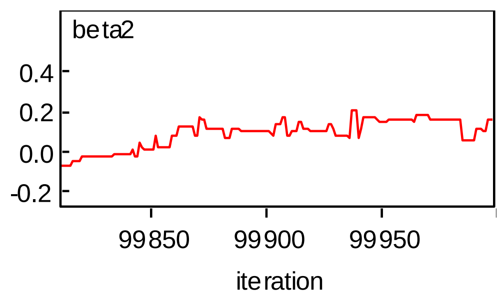
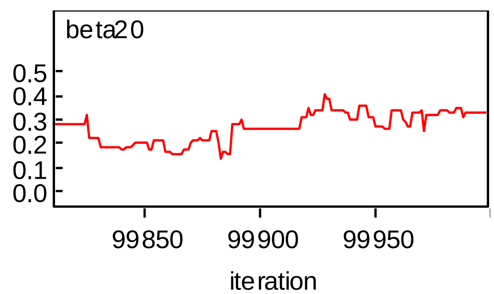
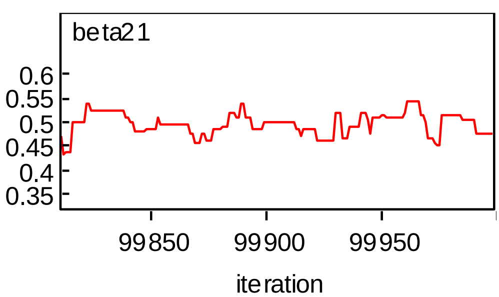
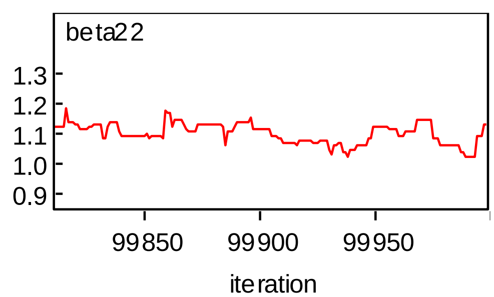
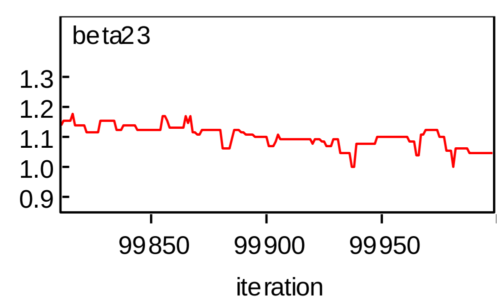
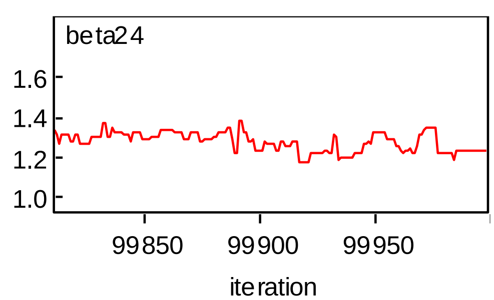
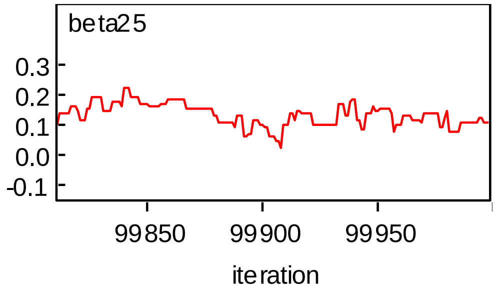
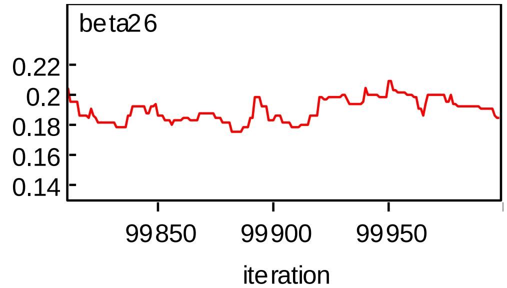

beta26
0.2
0.18
0.16
0.14
0.12
199850
199900
199950
iteration

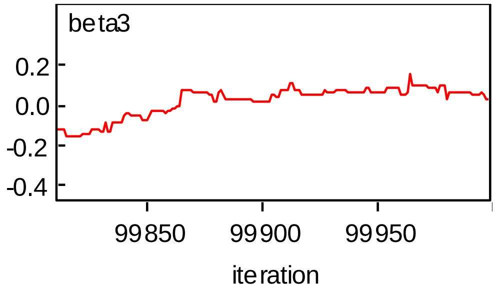
Figure 3: Trace plots for fixed effects model

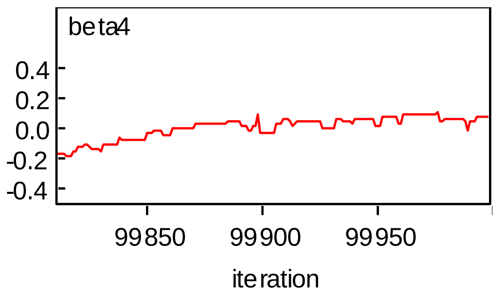


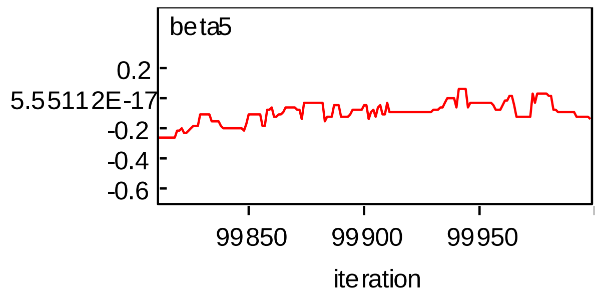

beta16
1.3
1.2
1.1
1.0
0.9
99850
99900
99950
iteration

beta17
0.5
0.4
0.3
0.2
0.1
99850
99900
99950
iteration

beta18
0.5
0.4
0.3
0.2
0.1
99850
99900
99950
iteration

beta19
0.6
0.5
0.4
0.3
0.2
99850
99900
99950
iteration

beta2
0.4
0.2
0.0
-0.2
99850
99900
99950
iteration

beta20
0.5
0.4
0.3
0.2
0.1
0.0
99850
99900
99950
iteration

beta21
0.6
0.55
0.5
0.45
0.4
0.35
99850
99900
99950
iteration

beta22
1.3
1.2
1.1
1.0
0.9
99850
99900
99950
iteration

beta23
1.3
1.2
1.1
1.0
0.9
99850
99900
99950
iteration

beta24
1.6
1.4
1.2
1.0
99850
99900
99950
iteration

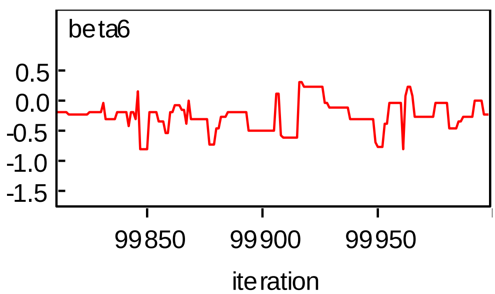

beta25
0.3
0.2
0.1
0.0
-0.1
99850
99900
99950
iteration

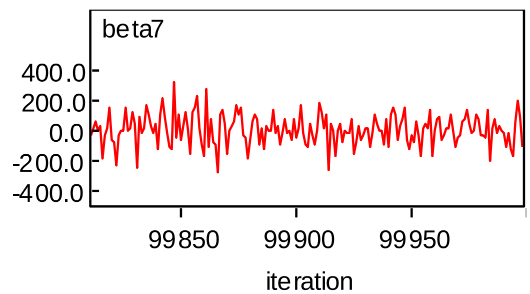

beta26
0.22
0.2
0.18
0.16
0.14
99850
99900
99950
iteration

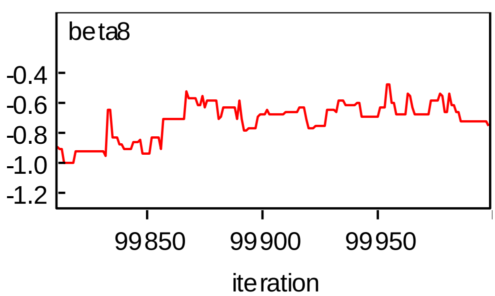

beta3
0.2
0.0
-0.2
-0.4
99850
99900
99950
iteration

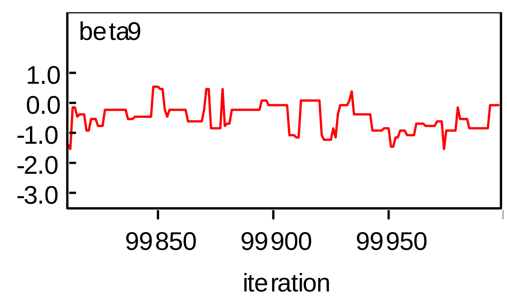

beta4
0.4
0.2
0.0
-0.2
-0.4
99850
99900
99950
iteration


beta5
0.2
5.55112E-17
-0.2
-0.4
-0.6
99850
99900
99950
iteration


beta6
0.5
0.0
-0.5
-1.0
-1.5
99850
99900
99950
iteration


beta7
400.0
200.0
0.0
-200.0
-400.0
99850
99900
99950
iteration


beta8
-0.4
-0.6
-0.8
-1.0
-1.2
99850
99900
99950
iteration


beta9
1.0
0.0
-1.0
-2.0
-3.0
99850
99900
99950
iteration

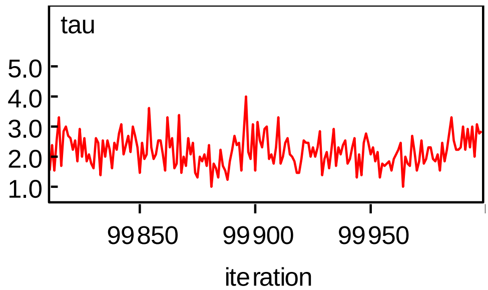
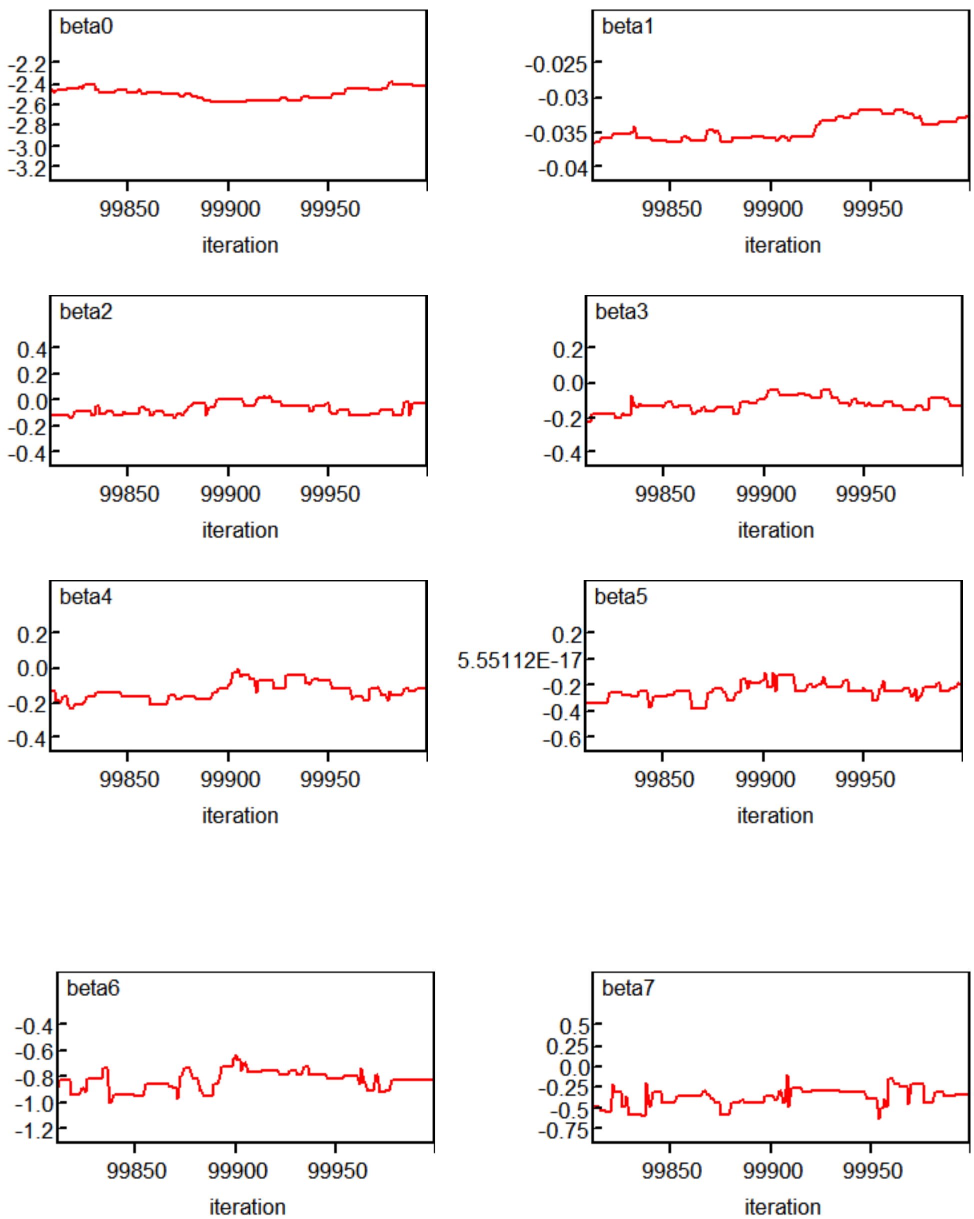
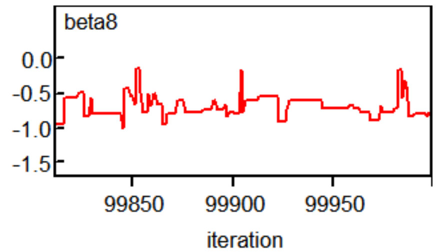
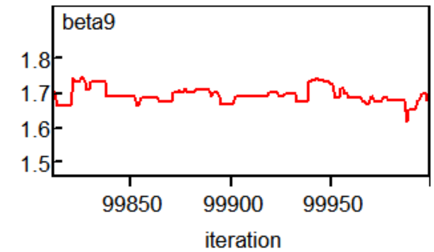
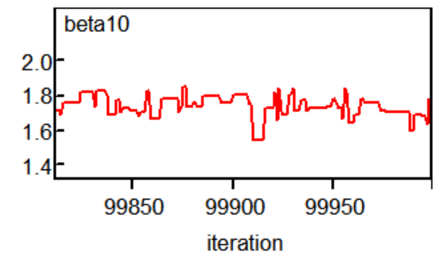


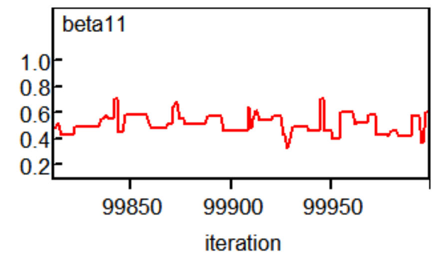
Figure 4: Trace plots for mixed effects model (non-spatial random effects)

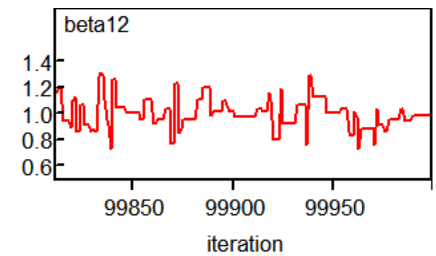


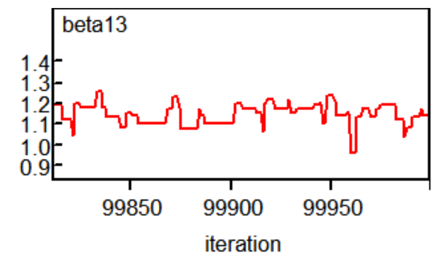

beta8
0.0
-0.5
-1.0
-1.5
99850
99900
99950
iteration

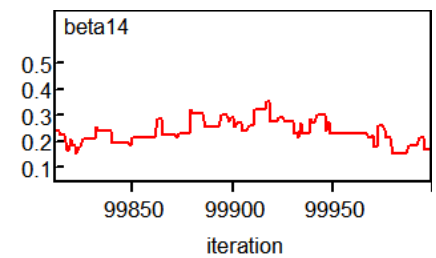

beta9
1.8
1.7
1.6
1.5
99850
99900
99950
iteration

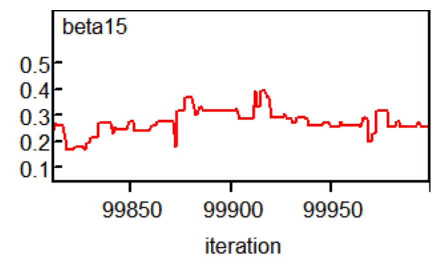

beta10
2.0
1.8
1.6
1.4
99850
99900
99950
iteration

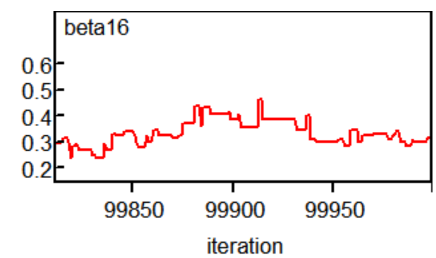

beta11
1.0
0.8
0.6
0.4
0.2
99850
99900
99950
iteration

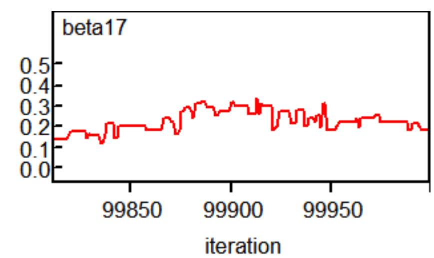

beta12
1.4
1.2
1.0
0.8
0.6
99850
99900
99950
iteration

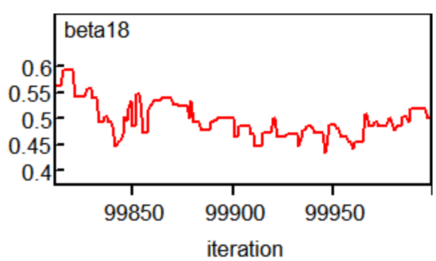

beta13
1.4
1.3
1.2
1.1
1.0
0.9
99850
99900
99950
iteration

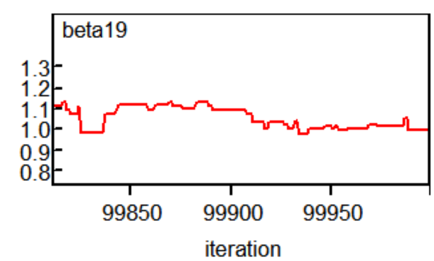

beta14
0.5
0.4
0.3
0.2
0.1
99850
99900
99950
iteration


beta15
0.5
0.4
0.3
0.2
0.1
99850
99900
99950
iteration


beta16
0.6
0.5
0.4
0.3
0.2
99850
99900
99950
iteration


beta17
0.5
0.4
0.3
0.2
0.1
0.0
99850
99900
99950
iteration


beta18
0.6
0.55
0.5
0.45
0.4
99850
99900
99950
iteration


beta19
1.3
1.2
1.1
1.0
0.9
0.8
99850
99900
99950
iteration

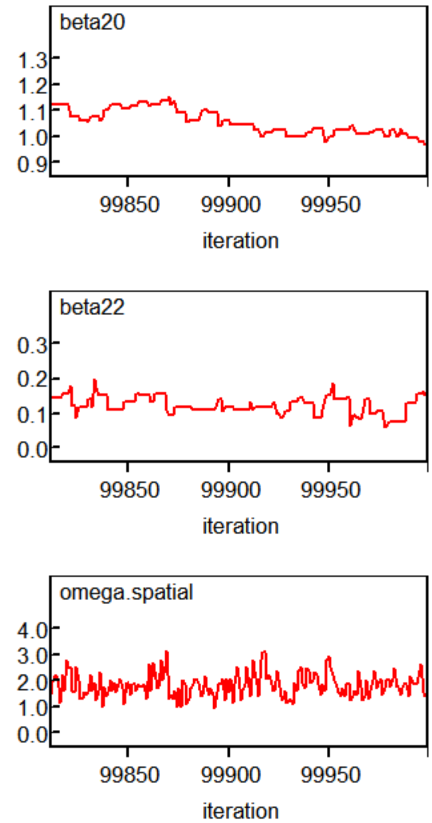
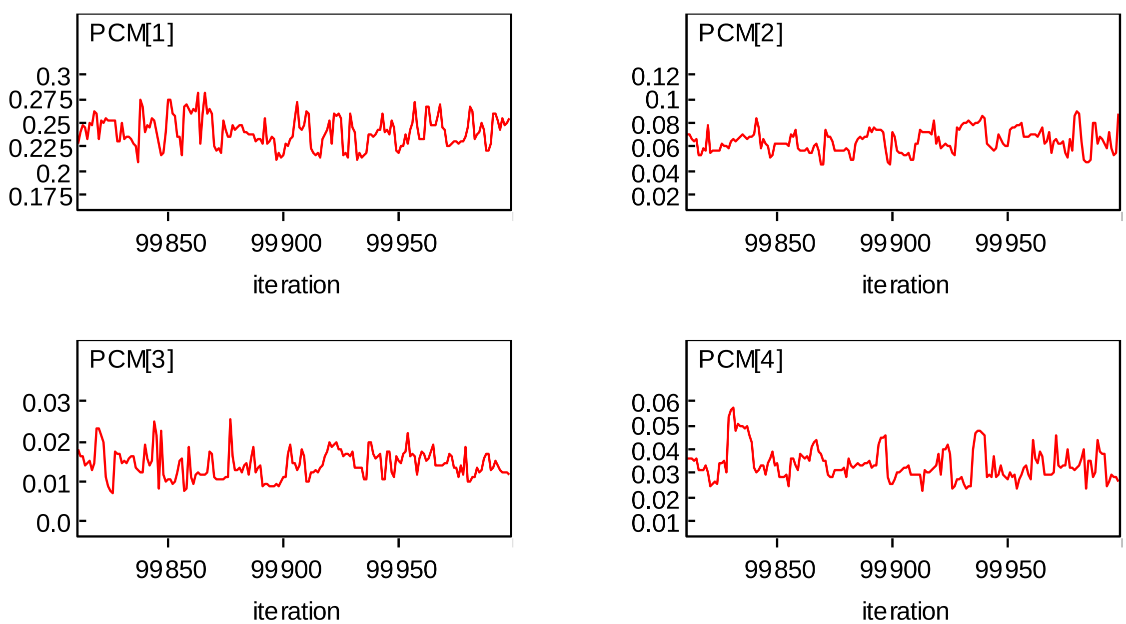
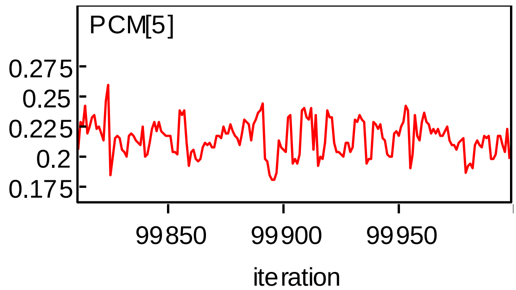
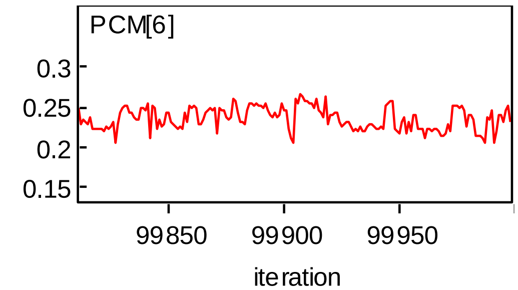
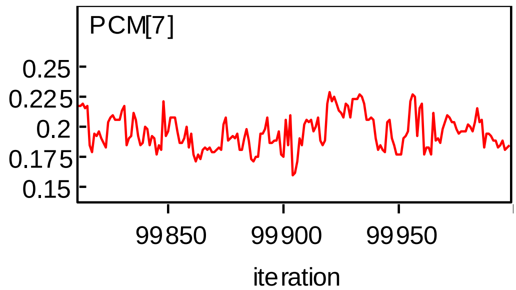


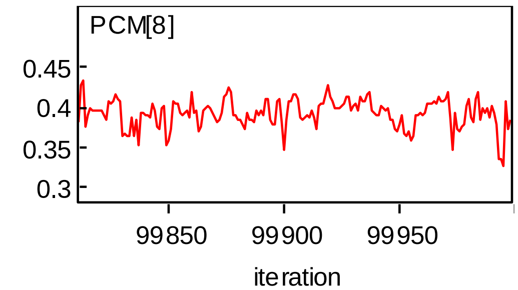
Figure 5: Trace plots for mixed effects model (spatial random effects)

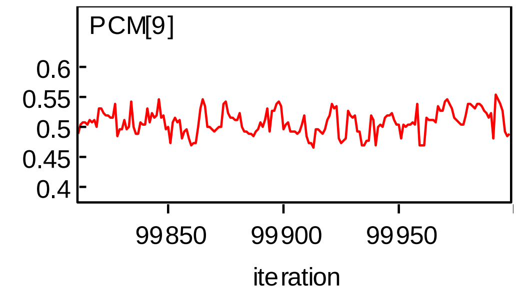


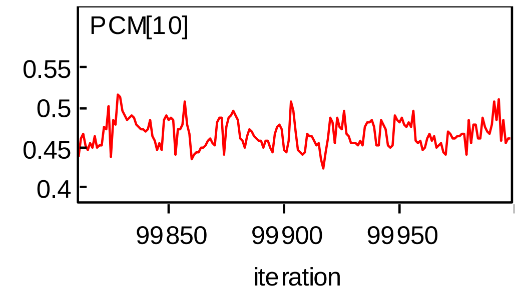

PCM[5]
0.275
0.25
0.225
0.2
0.175
99850
99900
99950
iteration

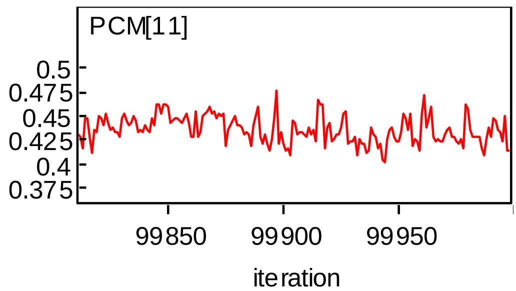

PCM[6]
0.3
0.25
0.2
0.15
99850
99900
99950
iteration

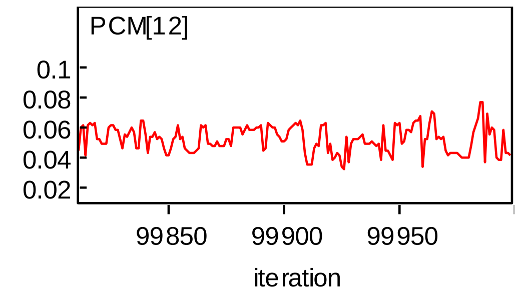

PCM[7]
0.25
0.225
0.2
0.175
0.15
99850
99900
99950
iteration

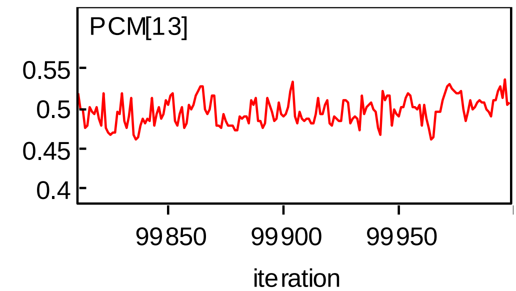

PCM[8]
0.45
0.4
0.35
0.3
99850
99900
99950
iteration

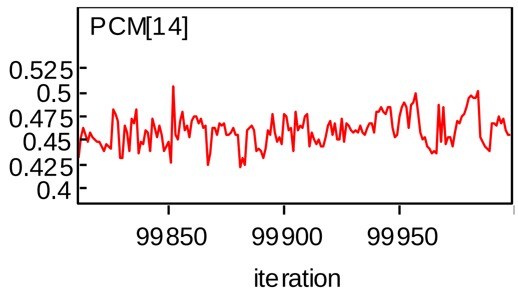

PCM[9]
0.6
0.55
0.5
0.45
0.4
99850
99900
99950
iteration

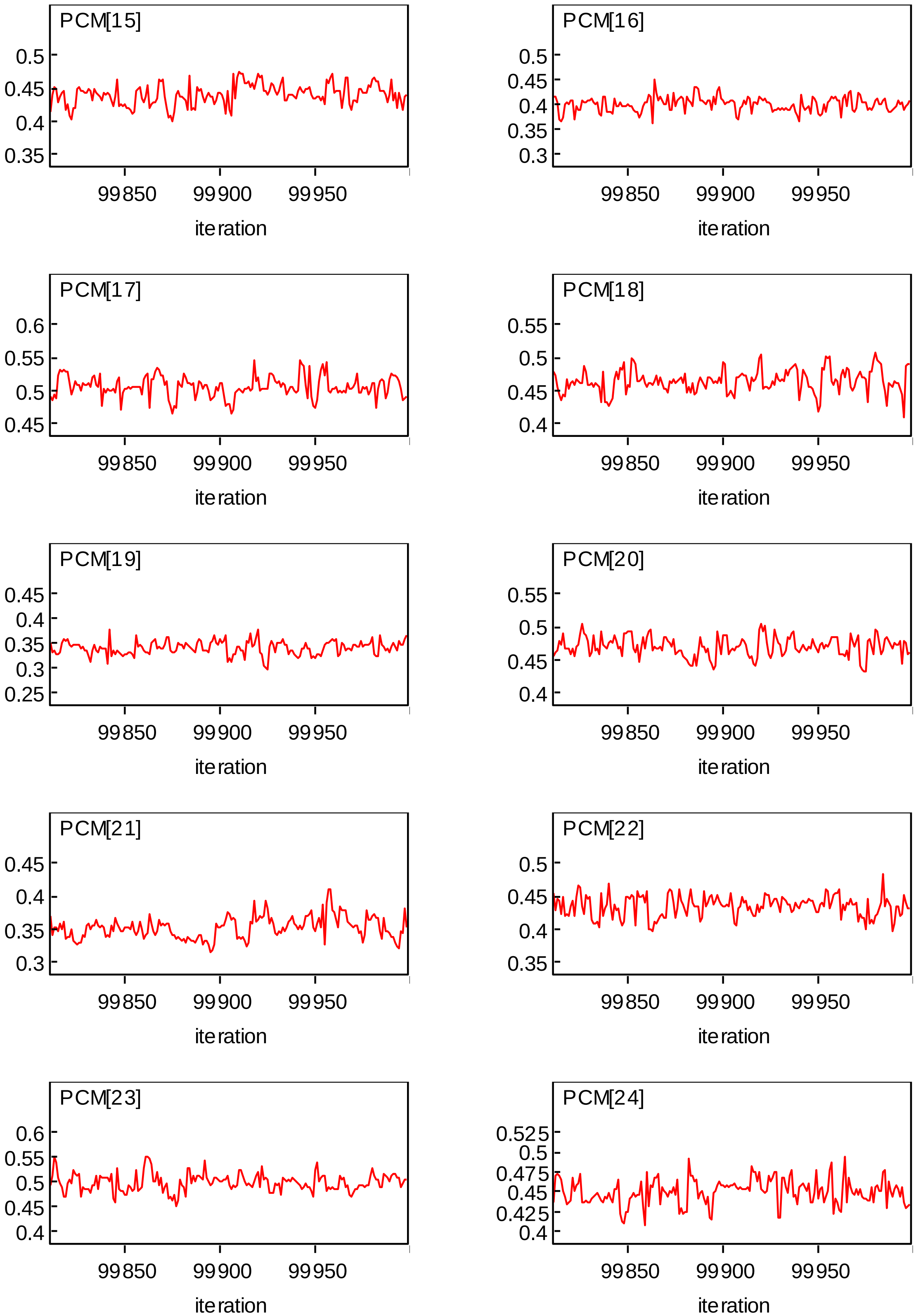

PCM[10]
0.55
0.5
0.45
0.4
99850
99900
99950
iteration

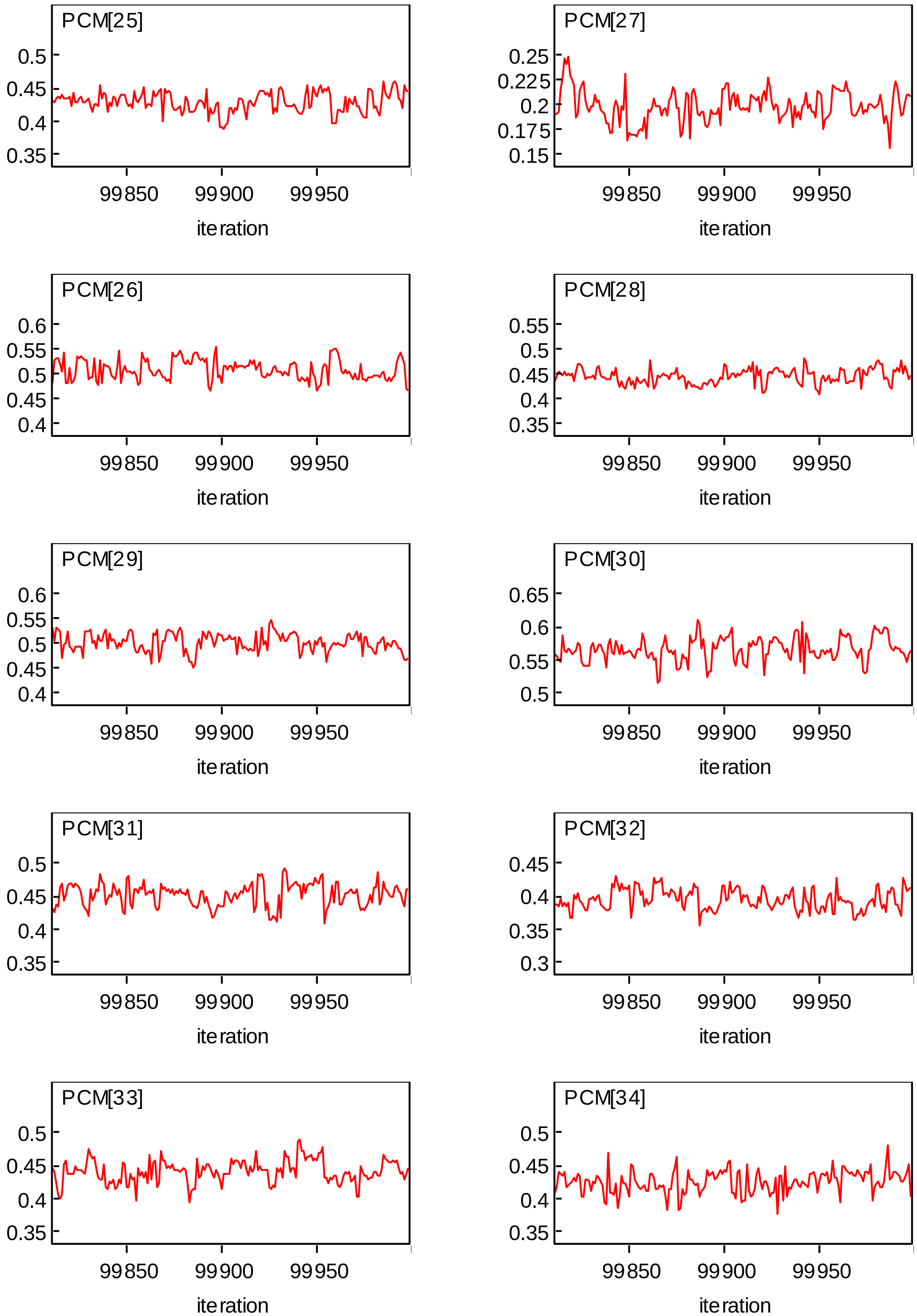

PCM[11]
0.5
0.475
0.45
0.425
0.4
0.375
99850
99900
99950
iteration

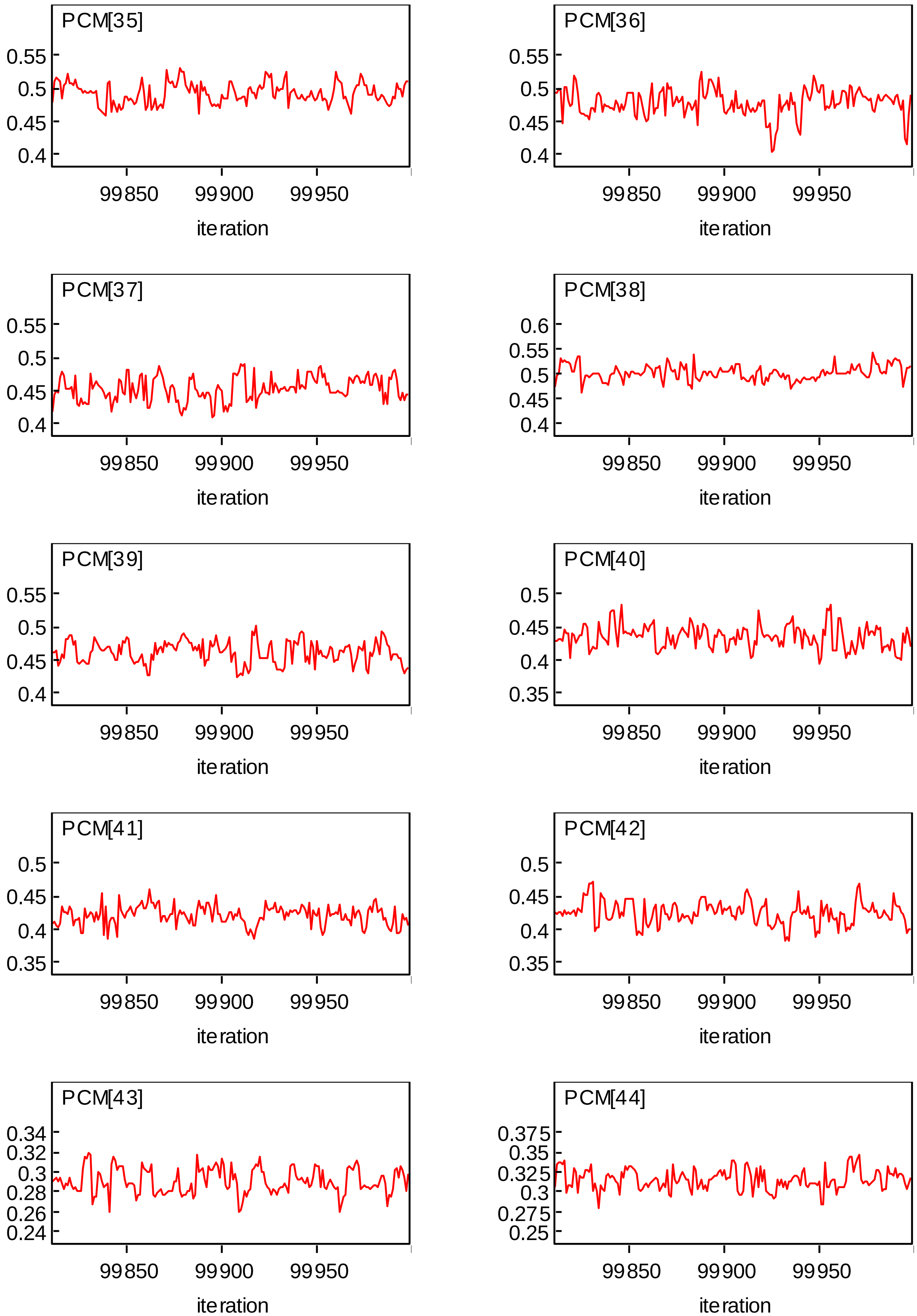

PCM[12]
0.1
0.08
0.06
0.04
0.02
99850
99900
99950
iteration

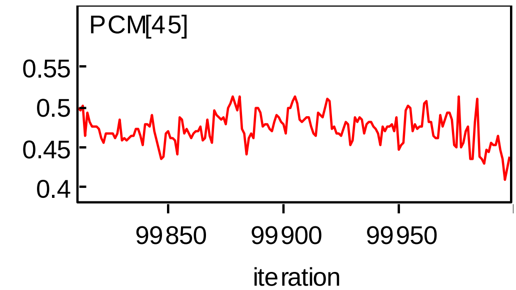

PCM[13]
0.55
0.5
0.45
0.4
99850
99900
99950
iteration

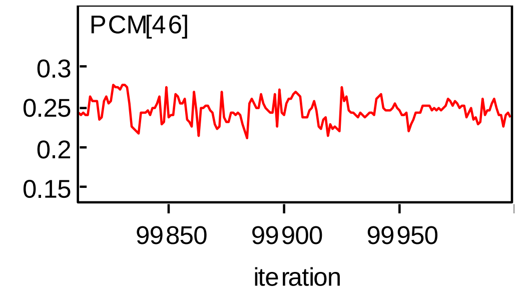

PCM[14]
0.525
0.5
0.475
0.45
0.425
0.4
99850
99900
99950
iteration

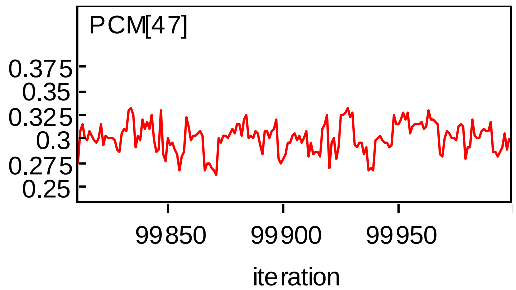

PCM[15]
0.5
0.45
0.4
0.35
99850
99900
99950
iteration
PCM[16]
0.5
0.45
0.4
0.35
0.3
99850
99900
99950
iteration
PCM[17]
0.6
0.55
0.5
0.45
99850
99900
99950
iteration
PCM[18]
0.55
0.5
0.45
0.4
99850
99900
99950
iteration
PCM[19]
0.45
0.4
0.35
0.3
0.25
99850
99900
99950
iteration
PCM[20]
0.55
0.5
0.45
0.4
99850
99900
99950
iteration
PCM[21]
0.45
0.4
0.35
0.3
99850
99900
99950
iteration
PCM[22]
0.5
0.45
0.4
0.35
99850
99900
99950
iteration
PCM[23]
0.6
0.55
0.5
0.45
0.4
99850
99900
99950
iteration
PCM[24]
0.525
0.5
0.475
0.45
0.425
0.4
99850
99900
99950
iteration

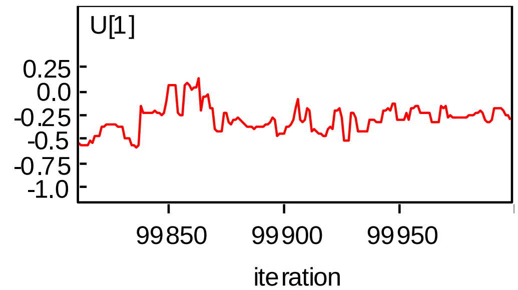

PCM[25]
0.5
0.45
0.4
0.35
99850
99900
99950
iteration
PCM[27]
0.25
0.225
0.2
0.175
0.15
99850
99900
99950
iteration
PCM[26]
0.6
0.55
0.5
0.45
0.4
99850
99900
99950
iteration
PCM[28]
0.55
0.5
0.45
0.4
0.35
99850
99900
99950
iteration
PCM[29]
0.6
0.55
0.5
0.45
0.4
99850
99900
99950
iteration
PCM[30]
0.65
0.6
0.55
0.5
99850
99900
99950
iteration
PCM[31]
0.5
0.45
0.4
0.35
99850
99900
99950
iteration
PCM[32]
0.45
0.4
0.35
0.3
99850
99900
99950
iteration
PCM[33]
0.5
0.45
0.4
0.35
99850
99900
99950
iteration
PCM[34]
0.5
0.45
0.4
0.35
99850
99900
99950
iteration

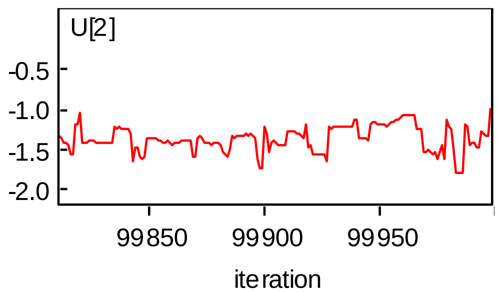

PCM[35]
PCM[36]
PCM[37]
PCM[38]
PCM[39]
PCM[40]
PCM[41]
PCM[42]
PCM[43]
PCM[44]
99850
99900
99950
iteration

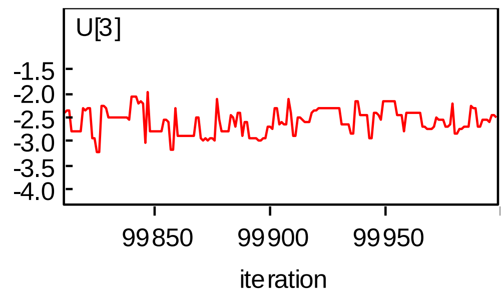

PCM[45]
0.55
0.5
0.45
0.4
99850
99900
99950
iteration

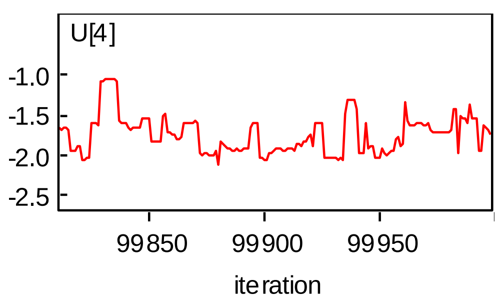

PCM[46]
0.3
0.25
0.2
0.15
99850
99900
99950
iteration

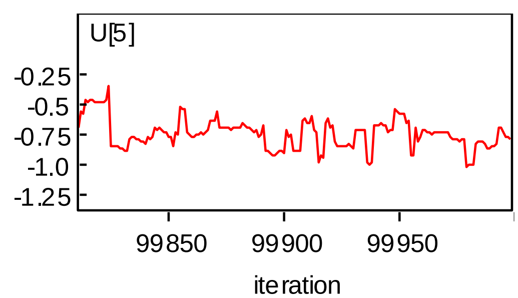

PCM[47]
0.375
0.35
0.325
0.3
0.275
0.25
99850
99900
99950
iteration

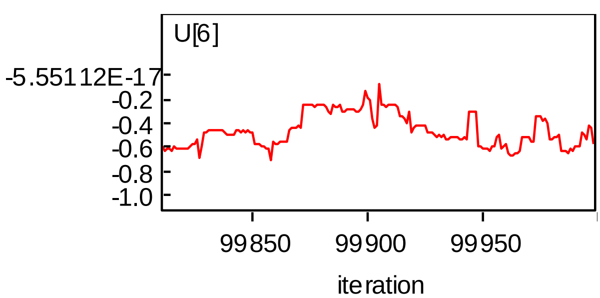

U[1]
0.25
0.0
-0.25
-0.5
-0.75
-1.0
99850
99900
99950
iteration

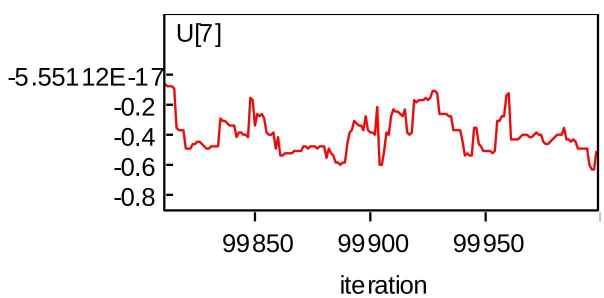

U[2]
-0.5
-1.0
-1.5
-2.0
99850
99900
99950
iteration

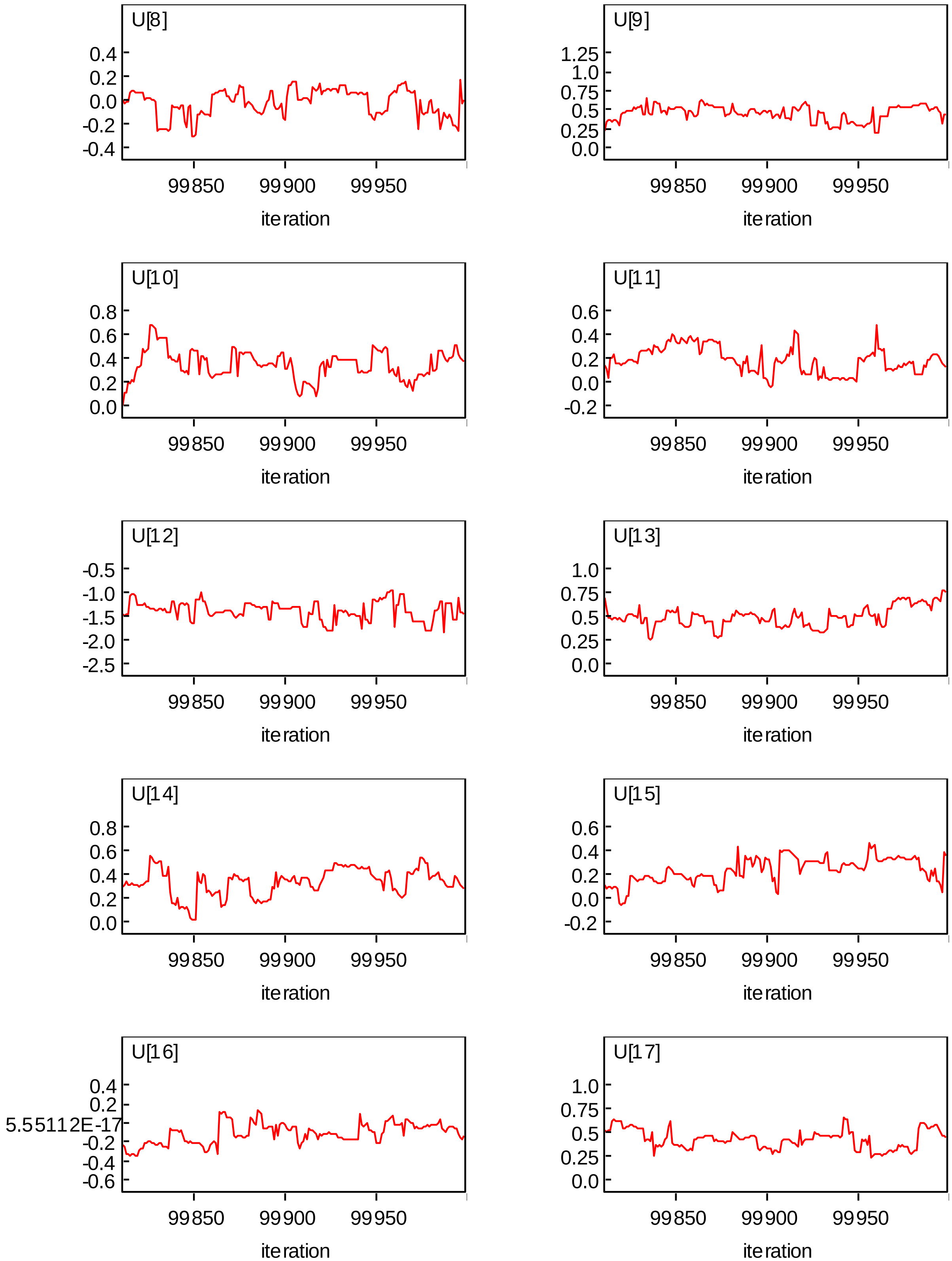

U[3]
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
99850
99900
99950
iteration

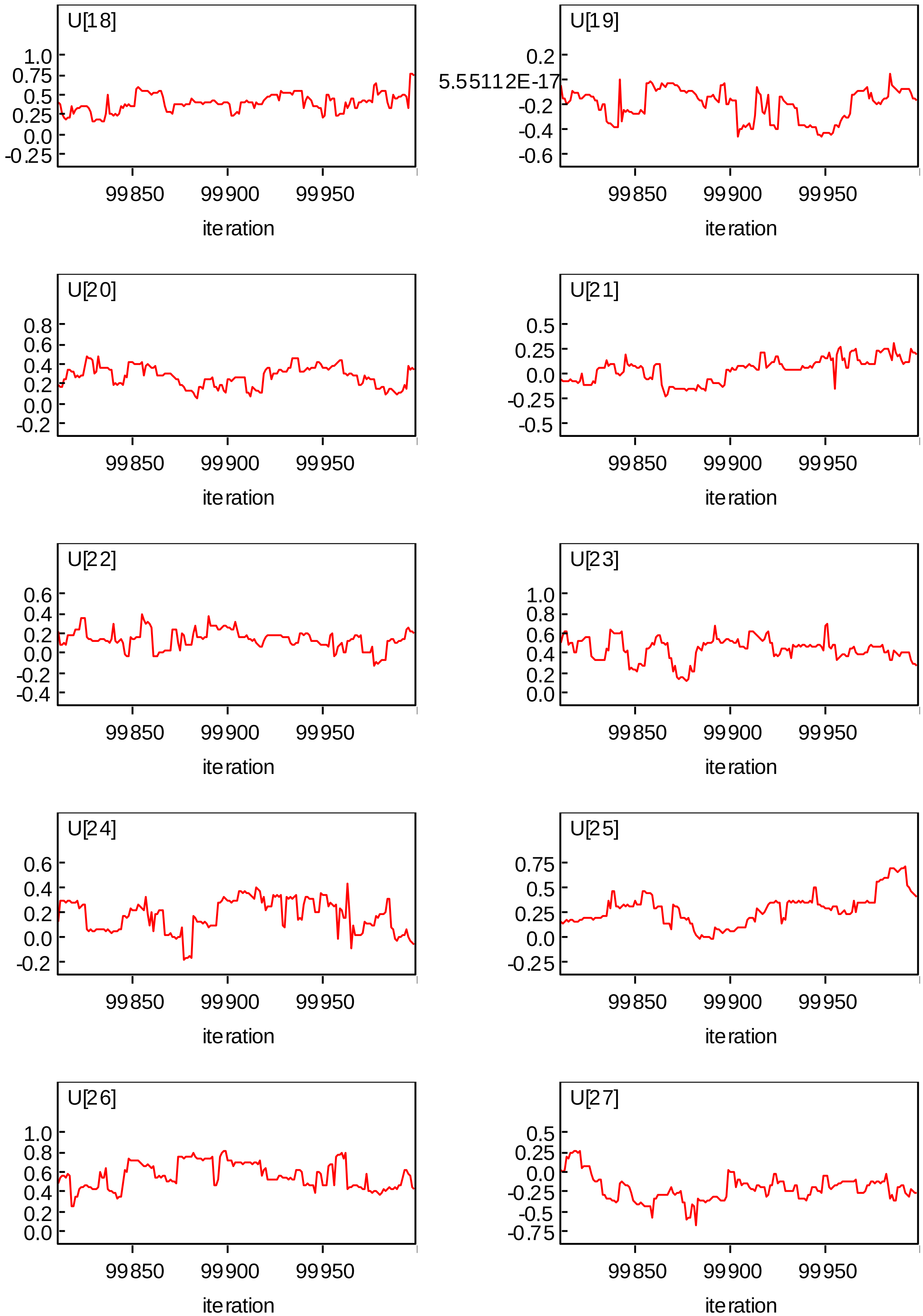

U[4]
-1.0
-1.5
-2.0
-2.5
99850
99900
99950
iteration

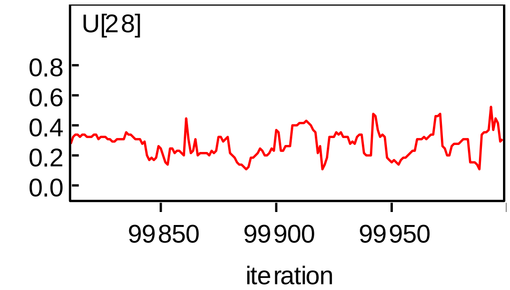

U[5]
-0.25
-0.5
-0.75
-1.0
-1.25
99850
99900
99950
iteration

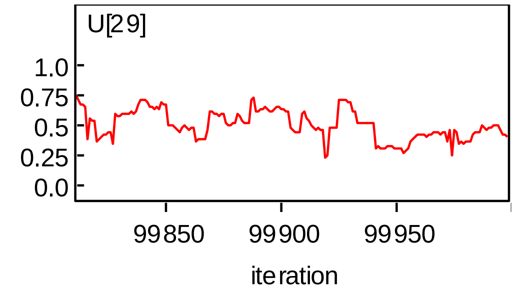

U[6]
-5.55112E-17
-0.2
-0.4
-0.6
-0.8
-1.0
99850
99900
99950
iteration

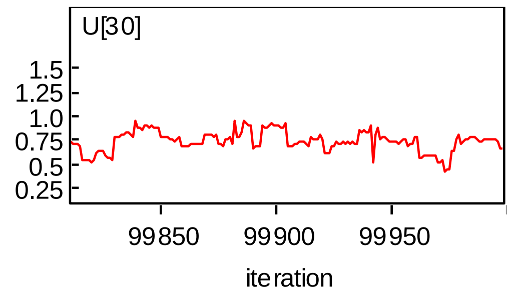

U[7]
-5.55112E-17
-0.2
-0.4
-0.6
-0.8
99850
99900
99950
iteration

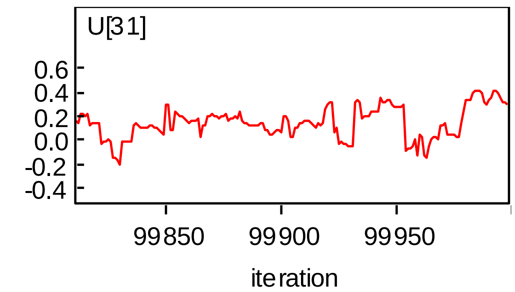

U[8]
0.4
0.2
0.0
-0.2
-0.4
99850
99900
99950
iteration
U[9]
1.25
1.0
0.75
0.5
0.25
0.0
99850
99900
99950
iteration
U[10]
0.8
0.6
0.4
0.2
0.0
99850
99900
99950
iteration
U[11]
0.6
0.4
0.2
0.0
-0.2
99850
99900
99950
iteration
U[12]
-0.5
-1.0
-1.5
-2.0
-2.5
99850
99900
99950
iteration
U[13]
1.0
0.75
0.5
0.25
0.0
99850
99900
99950
iteration
U[14]
0.8
0.6
0.4
0.2
0.0
99850
99900
99950
iteration
U[15]
0.6
0.4
0.2
0.0
-0.2
99850
99900
99950
iteration
U[16]
0.4
0.2
5.55112E-17
-0.2
-0.4
-0.6
99850
99900
99950
iteration
U[17]
1.0
0.75
0.5
0.25
0.0
99850
99900
99950
iteration

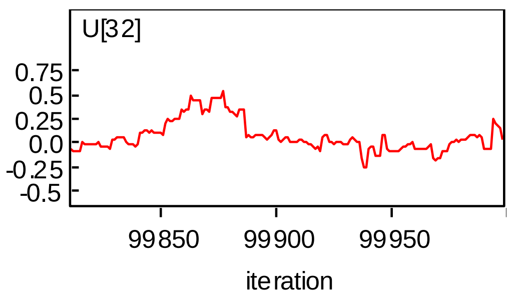

U[18]
1.0
0.75
0.5
0.25
0.0
-0.25
99850
99900
99950
iteration
U[19]
0.2
5.55112E-17
-0.2
-0.4
-0.6
99850
99900
99950
iteration
U[20]
0.8
0.6
0.4
0.2
0.0
-0.2
99850
99900
99950
iteration
U[21]
0.5
0.25
0.0
-0.25
-0.5
99850
99900
99950
iteration
U[22]
0.6
0.4
0.2
0.0
-0.2
-0.4
99850
99900
99950
iteration
U[23]
1.0
0.8
0.6
0.4
0.2
0.0
99850
99900
99950
iteration
U[24]
0.6
0.4
0.2
0.0
-0.2
99850
99900
99950
iteration
U[25]
0.75
0.5
0.25
0.0
-0.25
99850
99900
99950
iteration
U[26]
1.0
0.8
0.6
0.4
0.2
0.0
99850
99900
99950
iteration
U[27]
0.5
0.25
0.0
-0.25
-0.5
-0.75
99850
99900
99950
iteration

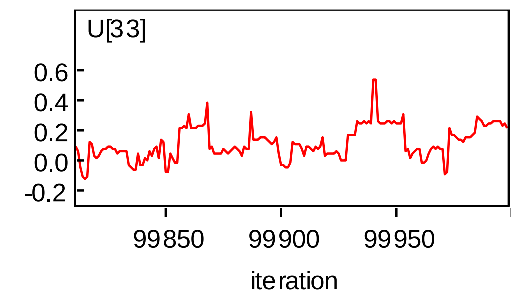

U[28]
0.8
0.6
0.4
0.2
0.0
99850
99900
99950
iteration

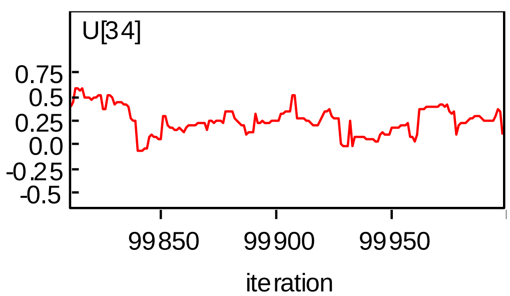

U[29]
1.0
0.75
0.5
0.25
0.0
99850
99900
99950
iteration

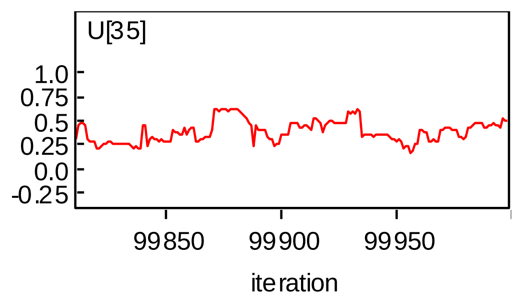

U[30]
1.5
1.25
1.0
0.75
0.5
0.25
99850
99900
99950
iteration

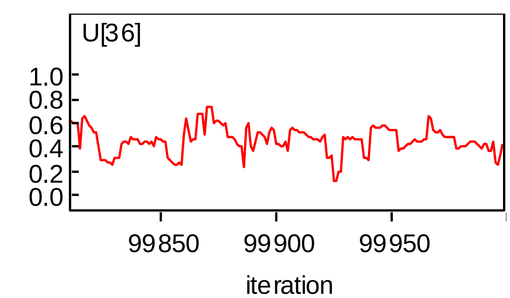

U[31]
0.6
0.4
0.2
0.0
-0.2
-0.4
99850
99900
99950
iteration

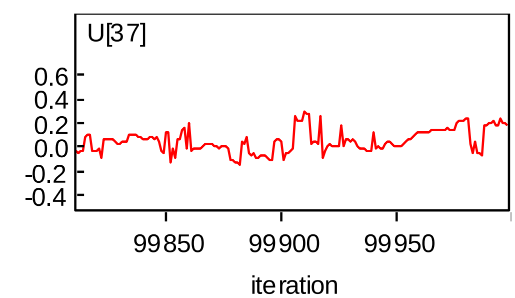

U[32]
0.75
0.5
0.25
0.0
-0.25
-0.5
99850
99900
99950
iteration

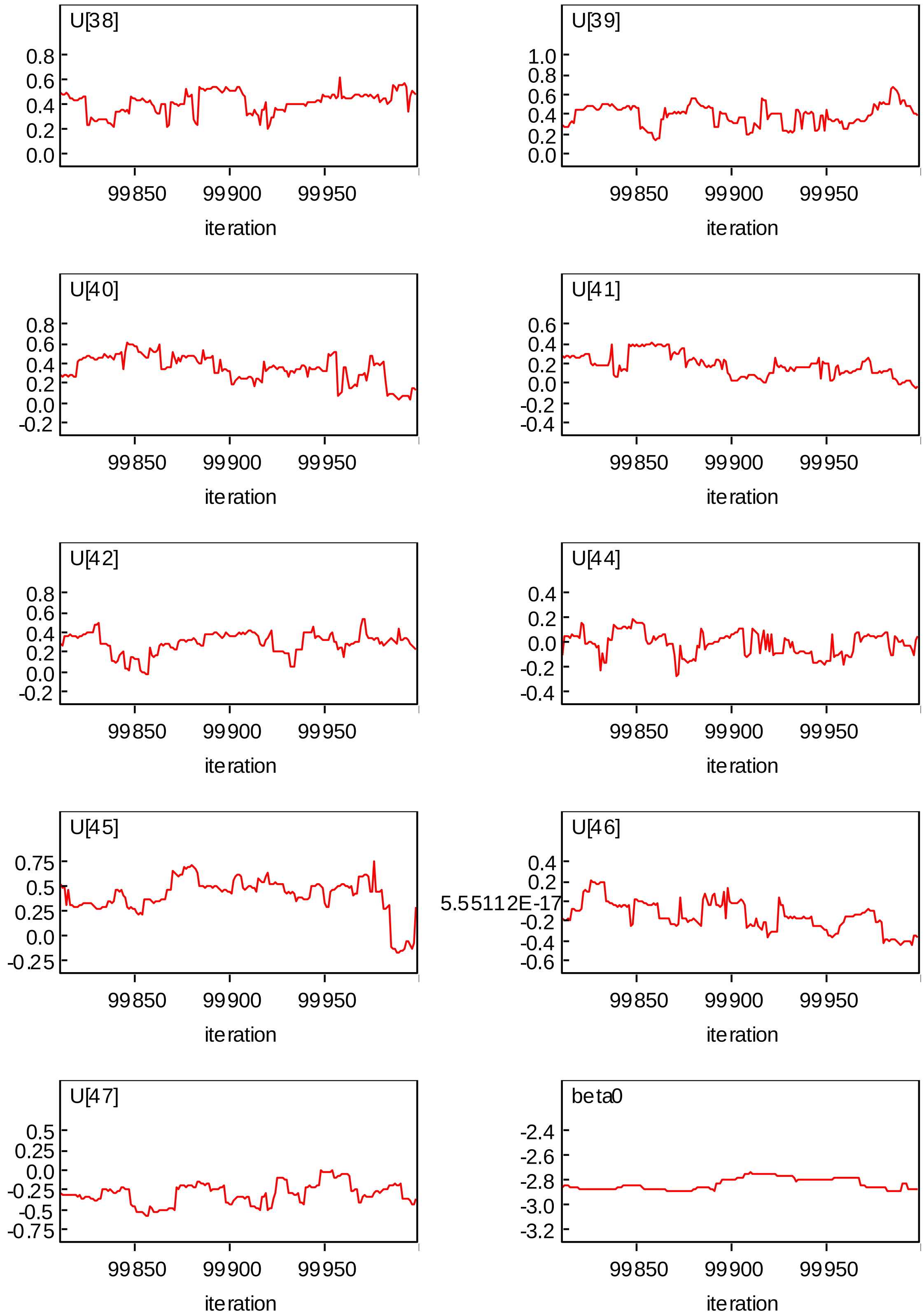

U[33]
0.6
0.4
0.2
0.0
-0.2
99850
99900
99950
iteration

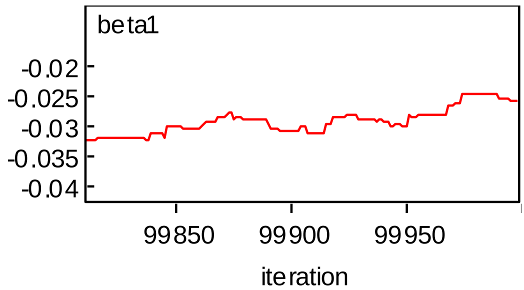

U[34]
0.75
0.5
0.25
0.0
-0.25
-0.5
99850
99900
99950
iteration

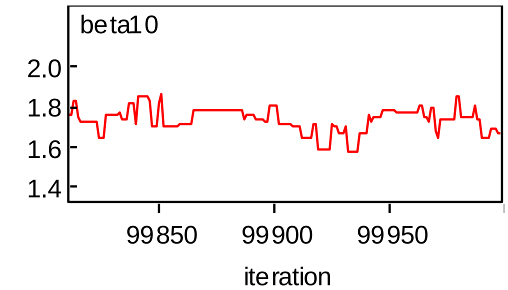

U[35]
1.0
0.75
0.5
0.25
0.0
-0.25
99850
99900
99950
iteration

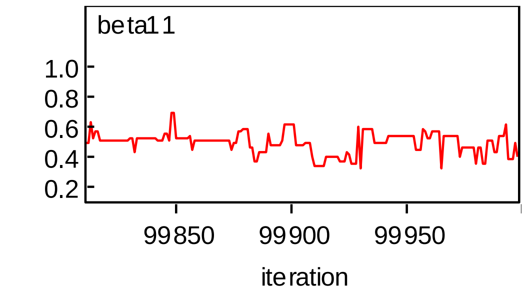

U[36]
1.0
0.8
0.6
0.4
0.2
0.0
99850
99900
99950
iteration

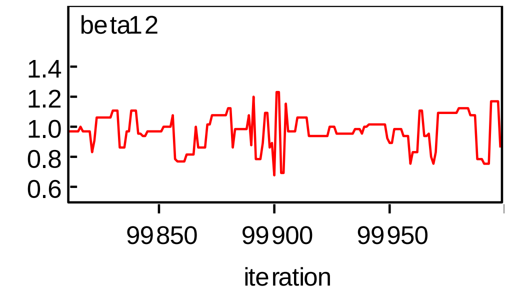

U[37]
0.6
0.4
0.2
0.0
-0.2
-0.4
99850
99900
99950
iteration

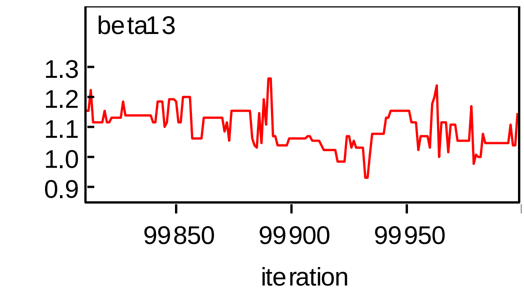

U[38]
0.8
0.6
0.4
0.2
0.0
99850
99900
99950
iteration
U[39]
1.0
0.8
0.6
0.4
0.2
0.0
99850
99900
99950
iteration
U[40]
0.8
0.6
0.4
0.2
0.0
-0.2
99850
99900
99950
iteration
U[41]
0.6
0.4
0.2
0.0
-0.2
-0.4
99850
99900
99950
iteration
U[42]
0.8
0.6
0.4
0.2
0.0
-0.2
99850
99900
99950
iteration
U[44]
0.4
0.2
0.0
-0.2
-0.4
99850
99900
99950
iteration
U[45]
0.75
0.5
0.25
0.0
-0.25
99850
99900
99950
iteration
U[46]
0.4
0.2
5.55112E-17
-0.2
-0.4
-0.6
99850
99900
99950
iteration
U[47]
0.5
0.25
0.0
-0.25
-0.5
-0.75
99850
99900
99950
iteration
beta0
-2.4
-2.6
-2.8
-3.0
-3.2
99850
99900
99950
iteration

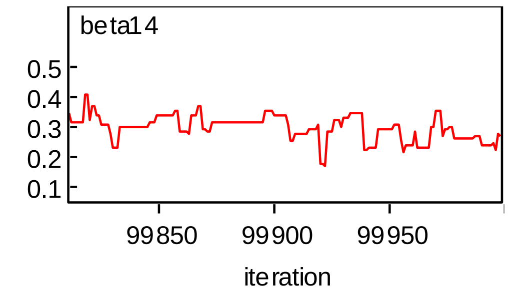

beta1
-0.02
-0.025
-0.03
-0.035
-0.04
99850
99900
99950
iteration

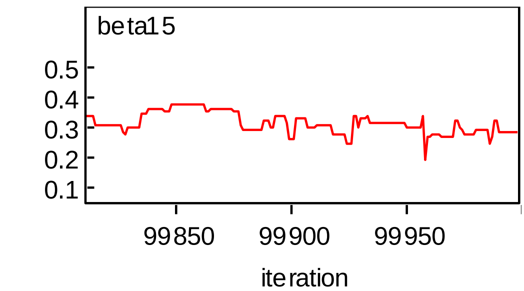

beta10
2.0
1.8
1.6
1.4
99850
99900
99950
iteration

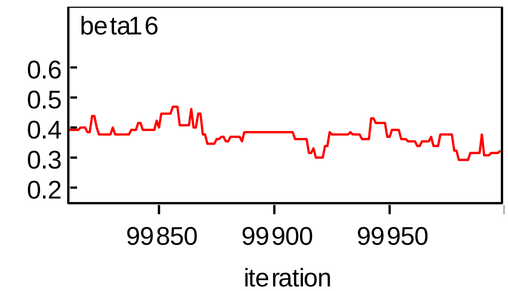

beta11
1.0
0.8
0.6
0.4
0.2
99850
99900
99950
iteration

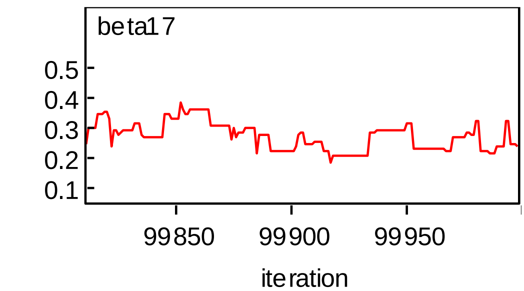

beta12
1.4
1.2
1.0
0.8
0.6
99850
99900
99950
iteration

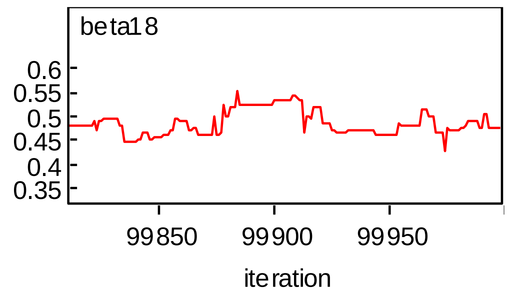

beta13
1.3
1.2
1.1
1.0
0.9
99850
99900
99950
iteration

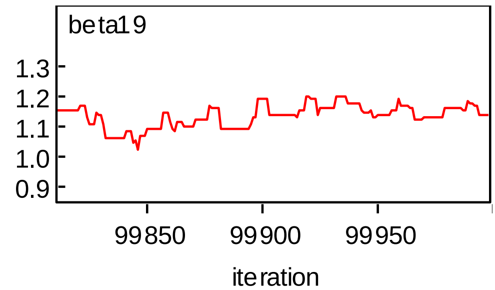

beta14
0.5
0.4
0.3
0.2
0.1
99850
99900
99950
iteration

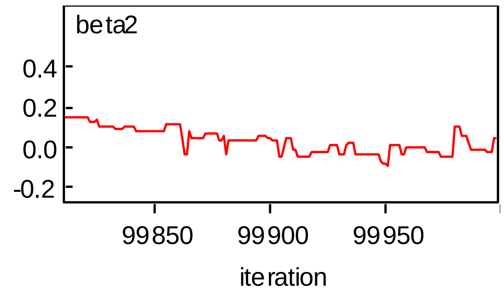

beta15
0.5
0.4
0.3
0.2
0.1
99850
99900
99950
iteration

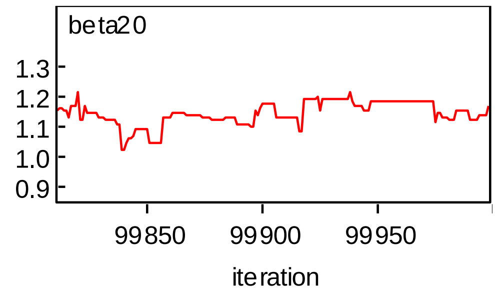

beta16
0.6
0.5
0.4
0.3
0.2
99850
99900
99950
iteration

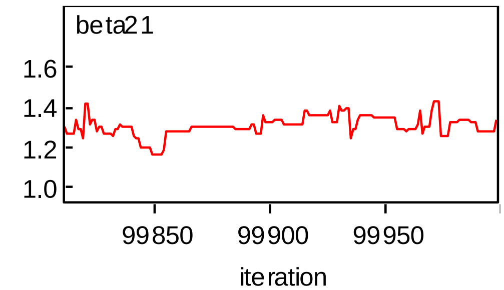

beta17
0.5
0.4
0.3
0.2
0.1
99850
99900
99950
iteration

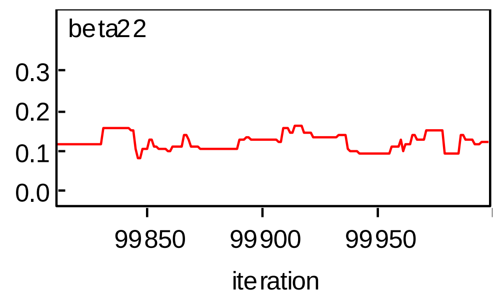

beta18
0.6
0.55
0.5
0.45
0.4
0.35
99850
99900
99950
iteration

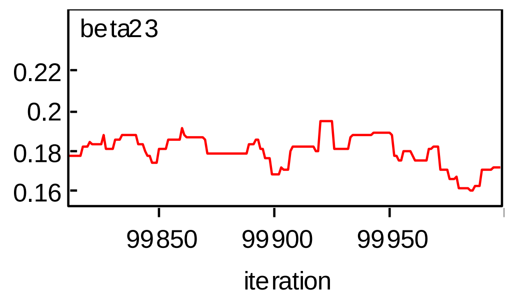

beta19
1.3
1.2
1.1
1.0
0.9
99850
99900
99950
iteration

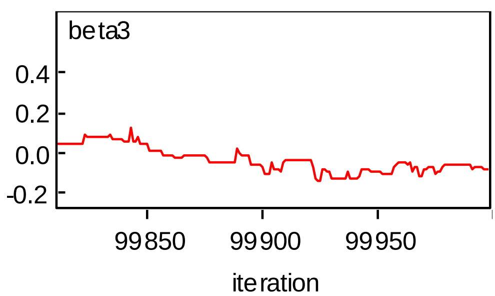

beta2
0.4
0.2
0.0
-0.2
99850
99900
99950
iteration

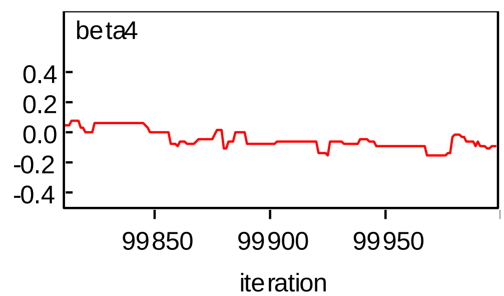

beta20
1.3
1.2
1.1
1.0
0.9
99850
99900
99950
iteration

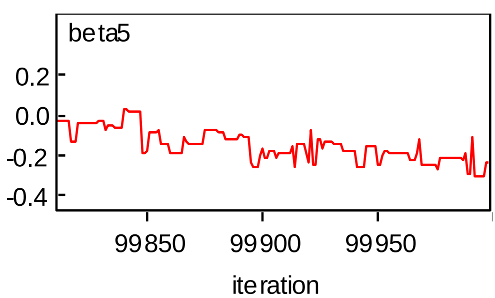

beta21
1.6
1.4
1.2
1.0
99850
99900
99950
iteration

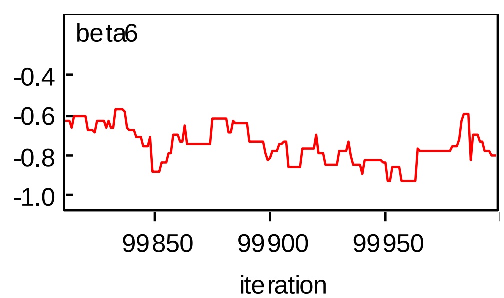

beta22
0.3
0.2
0.1
0.0
99850
99900
99950
iteration


beta23
0.22
0.2
0.18
0.16
99850
99900
99950
iteration


beta3
0.4
0.2
0.0
-0.2
99850
99900
99950
iteration


beta4
0.4
0.2
0.0
-0.2
-0.4
99850
99900
99950
iteration


beta5
0.2
0.0
-0.2
-0.4
99850
99900
99950
iteration


beta6
-0.4
-0.6
-0.8
-1.0
99850
99900
99950
iteration

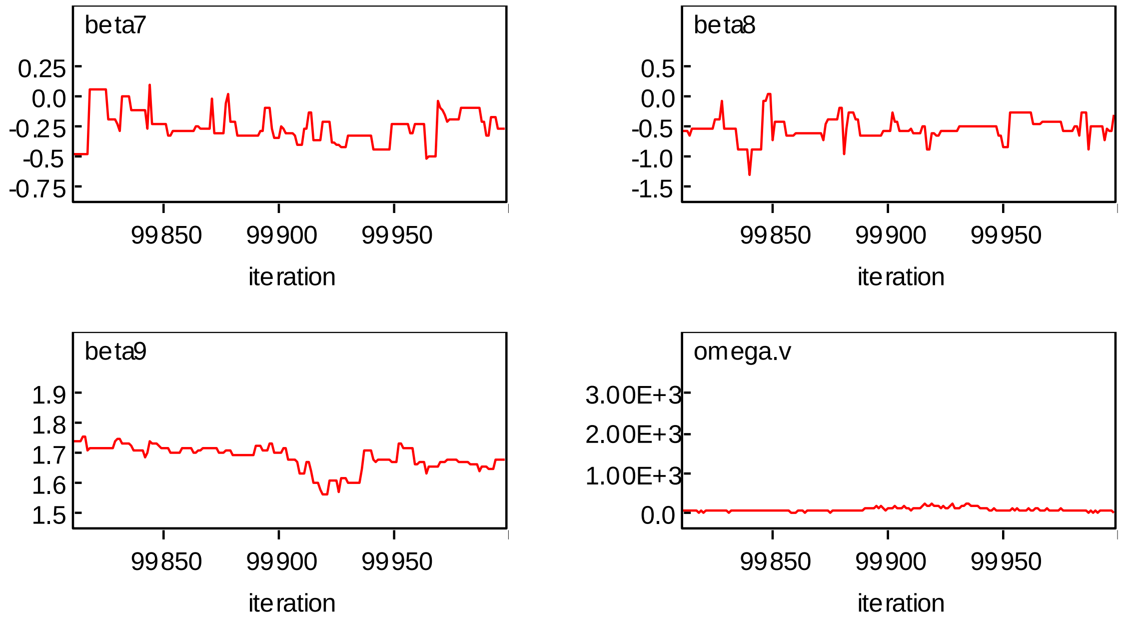


Figure 6: Trace plots for mixed effects model (spatial and non-spatial random effects)