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Addis Ababa University

ADDIS ABABA UNIVERSITY
GRADUATE STUDIES PROGRAMME
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DETERMINANTS OF IMMUNIZATION AMONG CHILDREN AGED 12-23 MONTHS IN ETHIOPIA: A PROPORTIONAL ODDS MODEL APPROACH

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School of Graduate Studies

This is to certify that the thesis prepared by Mesay Tefera, entitled: Determinants of Immunization Among Children Aged 12- 23 Months in Ethiopia: A proportional Odds Model Approach and submitted in partial fulfillment of the requirements for the Degree of Master of Science in Statistics (Applied Statistics) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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DECLARATION

I, the undersigned, declare that the thesis is my original work, has not been presented for degrees in any other University and all sources of materials used for the thesis have been duly acknowledged.

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This thesis has been submitted for examination with my approval as a University advisor.

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ACRONYMS

AIC	Akaike Information Criterion
BCG	Bacillus Calmette-Guerin vaccine
CDC	Centers for Disease Control and Prevention
CSA	Central Statistics Agency
EDHS	Ethiopian Demographic and Health Survey
EPI	Expanded Program on Immunization
DHS	Demographic and Health Survey
GAVI	Global Alliance for Vaccines and Immunization
HSDP	Health Sector Development Programme
MGD	Millennium Development Goals
MOFED	Ministry of Finance and Economic Development
OPV	Oral Polio Vaccine
OLS	Ordinary Least Squares
OR	Odds -Ratio
PCOL	Partial Constrained Ordered Logit
PO	Proportional Odds
PPOM	Partial Proportional Odds Model
PPOM-UR	Unrestricted Partial Proportional Odds Mode
RED	Reaching Every District Strategy
SAGE	Strategic Advisory Group of Experts on Immunization
UN	United Nations
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
VDPV	Vaccine Derived Poliovirus
WHO	World Health Organization

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Childhood immunization is the initiation of immunity through application of vaccine (WHO, 2008). It is recognized as one of the most cost-effective public health interventions to prevent morbidity and mortality caused by infectious diseases, particularly in a high-endemic setting (The World Bank 1993, 1994; WHO, UNICEF 2005; WHO, UNICEF, World Bank 2009). Each year, immunization averts an estimated 2-3 million deaths from diphtheria, tetanus, pertussis (whooping cough) and measles (UNICEF, WHO 2013).

Immunization has great potential to improve the health of people. It is considered important for improving child survival (Lee, 2005).The inception of public immunization campaigns has contributed in reducing vaccine preventable diseases and deaths globally. It is enshrined as one of the utmost medical accomplishment that has succeeded to save more lives than any other health care intervention in the 20th century(Wiysonge et al. 2009). And also immunization is reported to be second to clean water in reducing the burden of infectious diseases (Andre 2008). It is said to be the single most efficient and cost effective means of controlling these diseases (JAMA 2006; NSW 2003). This is evident in the drastic decline, and in some cases elimination, of certain infectious diseases since the introduction of vaccines in the 20th century (CDC 1999a; NSW 2003).

An immunization campaign carried out by the World Health Organization (WHO) from 1967 to 1977 eradicated the natural occurrence of smallpox. When the program began, the disease threatened 60% of the world's population and killed every fourth victim. Also polio is going to be eradicated. Since the launch by WHO and its partners of the Global Polio Eradication Initiative in 1988, infections have fallen by 99%, and some five million people have escaped paralysis. Between 1999 and 2003, measles deaths dropped worldwide by almost 40%, and some regions have set a target of eliminating the disease (WHO, 2011).

All countries have national immunization programmes, and in most developing countries, children under five years old are immunized with the standard WHO recommended vaccines that protect against eight diseases - tuberculosis, diphtheria, tetanus (including neonatal tetanus through immunization of mothers), pertussis, polio, measles, hepatitis B (HepB), and homophiles influenza (Hib). These vaccines BCG (tuberculosis vaccine), oral polio vaccine (OPV), diphtheria pertussis-tetanus (DPT) vaccine, hepatitis B (HepB) vaccine and measles vaccine are preventing more than 2-3 million child deaths each year.

The Ethiopian health policy had given emphasis to the prevention and control of major communicable diseases. Thus, in Ethiopia expanded program on immunization (EPI) was initiated in 1980. The objective of the National Immunization Policy was to reduce mortality and morbidity in children from the EPI target diseases through the immunization of all children under the age two in the first five year, but later after 1986 it was revised to focus children under one year of age in order the child exposure time to natural infection. The program had been planned to make immunization services available to 10% of the population in 1980 and to increase immunization access by 10% each year and reach to 100% coverage. Presently, there is no further study that has explored the determinants of full immunization in children aged 12-23 months and in relation to several mothers or caregiver's and father or partner socio-demographic variables like Mothers education, father/partner education sex of child, place of residence, wealth index (household) , child place of delivery ,birth order of the child and region of residence; as well as access to media factors by evaluating factors like radio ownership. Exploring the associations based on these parameters can substantially assist with determining practical interventions that are efficient and cost-effective in the healthcare delivery system of vaccines in Ethiopia. The knowledge and data accrued would enable planning of cost effective and efficient vaccine programs in stopping vaccine preventable diseases like polio, measles, tetanus, pertussis, diphtheria and tuberculosis in children in Ethiopia.

1.2 Statement of the Problem

According to the Ethiopian Demographic and Health Survey (EDHS 2011), only 24 % of children age 12-23 months was fully immunized at the time of the survey. While this represents a 19% increase from the level reported in the 2005 EDHS, the percentage of children who are fully vaccinated remains far below the goal of 66% coverage set in the HSDP IV (MOH, 2010). A relatively high percentage of children received the first DPT dose (64 %). However, only 37% received the third dose of DPT, reflecting a dropout rate of 43%. More than eight children of every ten (82%) received the first dose of polio, but only about four in ten (44 %) received the third dose, reflecting a dropout rate of 46%.

Although there is a progressively big improvement in the health status of individuals in Ethiopia, infant and child mortalities are still intolerably high on global and regional standards. Many studies have examined those childhood morbidities and mortalities but it needs critical analysis of the hidden dimensions in the health or heath care issues of the future generation. And there are no adequate researches that can tell about factors associated with failure to realize full immunization in children in Ethiopia. Therefore, this study is an attempt to fill the research gap by identifying the socio-economic and demographic factors that determine immunization among children aged 12 – 23 months old in Ethiopia.

1.3 Objectives of the Study

General Objective

The general objective of the study is to identify the determinant factor affecting of immunization among children aged 12-23 months in Ethiopia.

The specific objectives of this study are:

- To identify socio-economic and demographic factors which are associated with immunization among children aged 12-23 months old in Ethiopia.
- To estimate the model that shows the relationship between immunization status among children aged 12-23 months and socio-economic and demographic variables.

CHAPTER TWO

LITERATURE REVIEW

2.1 Expanded Program on Immunization Target Disease and Vaccines

The EPI covers six most common vaccine preventable diseases which to a great extent affect children. These include tuberculosis, measles, poliomyelitis, whooping cough, diphtheria and tetanus, other diseases were also added to the EPI program. These include yellow fever and hepatitis. Currently, the EPI administers eight vaccines: BCG (tuberculosis vaccine), oral polio vaccine (OPV), diphtheria pertussis-tetanus (DPT) vaccine, hepatitis B (HepB) vaccine, measles vaccine, yellow fever vaccine, and heamophilus influenza type b and tetanus toxoid (TT) vaccines. In Ethiopia, currently the EPI program has eight vaccine preventable diseases. And vaccination is given on routine. The routine vaccinations services are given starting from birth and should be completed before one year of life by all children (UNICEF,WHO, 2012).

2.2 Global Immunization Coverage

In 1974, WHO established the Expanded Programme on Immunization to ensure that all children had access to routinely recommended vaccines. Despite improvement in global coverage with the third dose of diphtheria– tetanus–pertussis vaccine (DTP) from 5% in 1974, about one fifth of the world’s children had not completed the 3-dose DTP series by 2011. During 2012, an estimated 83% of infants worldwide received at least 3 doses of DTP vaccine, identical to estimates in 2010 and 2011. Among 194 WHO member states, 131 (68%) achieved 90% and above DTP3 coverage and 59 (30%) achieved 80% and above DTP3 coverage in every district. However, 22.6 million children did not receive 3 DTP doses (WHO, 2013).

In 2012, an estimated 83% (111 million) of infants worldwide were vaccinated with three doses of diphtheria-tetanus-pertussis (DTP3) vaccine. Three regions, the Americas, Europe and Western Pacific- maintained over 90% DTP3 immunization coverage, the Western Pacific reaching 97% (WHO, 2012).

During 2000-2011, improvements in vaccination coverage translated into decreases in the number of children who remain unimmunized. For example, the number of children unimmunized with DTP3 decreased by 93% in East Asia (from 2.9 million in 2000 to less than 200,000 in 2011 following an increase in coverage from 85% in 2000 to 99% in 2011), 32% in Southern Asia (from 12.8 million in 2000 to 8.7 million in 2011 following on an increase in coverage from 65% in 2000 to 76% in 2011) and by 27% in Sub-Saharan Africa (from 11.9 million in 2000 to 8.7 million in 2011; DTP3 coverage increase from 52% in 2000 to 71% in 2011) regions, three regions which account for almost two-thirds of the global target population for routine immunization. Despite these gains, an estimated 22.4 million children did not receive three doses of DTP containing vaccine before their first birthday during (UNICEF,WHO, 2012).

In 2008, global routine coverage with the first dose of measles-containing vaccine reached 83%, an increase from 72% in 2000. More than 110 million children received measles-containing vaccine through supplementary immunization activities in the 47 priority countries identified as having a high measles mortality burden in 2000 (WHO, 2009).

Notably, deaths due to measles worldwide decreased by a remarkable 74% between 2000 and 2007 from 750,000 to 197 000 and it is estimated that during this period, 11 million measles deaths were averted globally as a result of measles control activities(WHO,2008).

The eradication of poliomyelitis is imminent though there are still some unfolding challenges. Since the launch of the Global Polio Eradication in 1988, the incidence of polio reduced by more than 99% and an estimated five million people are protected from paralysis by the wild poliovirus. Polio is reported to be endemic in only four countries in the world. (WHO, 2009).

Among the 22.6 million children who did not receive 3 DTP doses during the first year of life, 12.4 million (55%) lived in 3 countries. These are India (30%), Nigeria (17%) and Indonesia (7%) and 16.3 million (72%) lived in 10 countries. An estimated 12.6 million (56%) children did not receive the first DTP dose, while nearly 10 million (44%) started, but did not complete, the 3-dose DTP series (UNICEF,WHO, 2013).

Among all incompletely vaccinated(partially immunized) childrenworldwide, nearly 8.4 million received at least one DTP dose, but did not complete the 3-dose series; however, 14 million (62%) never received the first DTP dose. Factors associated with under-vaccination may differ from those associated with non-vaccination. For example, immunization system weaknesses (e.g. inadequate vaccine supply, poor health worker availability and knowledge, insufficient political and financial support) are more commonly associated with under-vaccination, whereas parental attitudes and knowledge about immunization appear to play a greater role among unvaccinated children. To achieve improvements in vaccination coverage globally, multi-faceted and country-specific strategies will be required to address factors contributing to incomplete infant vaccination, particularly in countries with largest numbers of incompletely vaccinated children (WHO, 2009)..

In 2013 only 59 (30%) countries were assessed to have met the coverage target of at least 90% nationally and 80% in every district (or similar administrative level) with three doses of DTP-containing vaccines (DTP3) in children less than 12 months of age. Many countries mainly in the African, Eastern Mediterranean and South-East Asia regions will not meet routine immunizations coverage targets by 2015.Even more worrying is that immunization coverage has remained low, stagnant or even decreasing in several of these countries. These countries should urgently intensify efforts to improve programme performance, utilizing administrative and survey data to direct their corrective actions. Civil society needs to be meaningfully engaged in policy dialogues so that reasons for low coverage are better understood and interventions are tailored to address identified problems. Countries, agencies and all development partners must engage with the vaccine industry to closely monitor the global supply of vaccines and ensure sufficient supply into the future. They should anticipate and take timely actions to mitigate the risks of vaccine supply shortfalls that contribute to low coverage (WHO,Strategic Advisory Group of Experts (SAGE) on Immunization ,2013)

Three WHO regions: Africa, Europe and the Eastern Mediterranean are not on track to meet their regional measles elimination goals. Several countries in these regions are also at risk to miss the interim global targets for 2015 to increase coverage of routine immunization to greater than 90%

at the national level and 80% in every district, reduce measles incidence to fewer than five cases per million and reduce measles mortality by 95% (compared to 2000). Efforts to control rubella and CRS are also not getting the required attention in many regions and countries (WHO,Strategic Advisory Group of Experts (SAGE) on Immunization ,2013).

By 2015, all countries should reach 90% national immunization coverage and 80% in every district (or equivalent administrative unit) with three doses of diphtheria-tetanus-pertussis-containing vaccine (DTP3). By the end of the decade, all countries should reach similar goals for all vaccines included in their national programmes(WHO,Strategic Advisory Group of Experts (SAGE) on Immunization ,2013).

In 2012, only 30% of countries met the target of at least 90% coverage nationally and 80% in every district (or equivalent administrative unit). In several countries, coverage is below 80% and has remained stagnant; in some regions, warfare, civil strife and large-scale migration have resulted in sudden drops in coverage(WHO,Strategic Advisory Group of Experts (SAGE) on Immunization ,2013).

The huge amount of resources and efforts committed by WHO, UNICEF and World Bank (WHO and UNICEF 2005, 2009) at ensuring full immunization of children all over the world were justified in 2007 when out of 129 million surviving children, a total of 105 million (about 81 %) children under one year of age were vaccinated worldwide with three doses of diphtheria, pertussis and tetanus (DPT3) vaccine while the number of unvaccinated children decreased to 24 million from 33 million reported in the year 2000 (Duclos et al. 2009).

In 2002,WHO estimated that about 1.9 million of the 2.5million(76%) vaccine preventable worldwide deaths among children age less than five years occurred in Africa or South East Asia (JAMA 2006). Among these childhood deaths, over 500,000 were cause by measles; nearly 400,000 by Haemophilus influenza B; 300,000 by pertussis; and 180,000 by neonatal tetanus (WHO 2004).

2.3 Immunization Coverage in Africa

In the Sub-Saharan Africa it is estimated that 24 million children do not have access to basic immunization services (WHO, 2008).

Every year more than 10 million children in low- and middle-income countries die before they reach their fifth birthdays. Most die because they do not access effective interventions that would combat common and preventable childhood illnesses. Infant immunization is considered essential for improving infant and child survival. Although global immunization coverage has increased during the past decade to levels of around 78% for diphtheria–tetanus–pertussis-3 (DTP-3), WHO's African Region has consistently fallen behind, reaching only 69% DTP-3 coverage by 2004 (WHO,2007).

In response to challenges in global immunization, WHO and the United Nations Children's Fund (UNICEF) set up the Global Immunization Vision and Strategy (GIVS) in 2003. The chief goal of GIVS is to reduce illness and death due to vaccine-preventable diseases by at least two-thirds by 2015 or earlier. The Task Force on Immunization in Africa (TFI) recognized from the outset the need for high vaccination coverage to counter the disproportionate burden from vaccine-preventable diseases in the African Region, and therefore set challenging goals for 2001–2005.

These goals aimed to ensure that the immunization performance of the African Region caught up with other regions performance. (WHO,2007).

An important aspect to note is that more than seventy percent of these children live in ten countries (including five African country) namely; Afghanistan, Chad, Democratic Republic of the Congo, Ethiopia, India, Indonesia, Nigeria, Pakistan, Philippines and South Africa. This makes these countries to be the hub of these virulent viruses and pose challenges on measures towards eradication. (WHO, 2012). Half of all unvaccinated children live in India, Indonesia and Nigeria. These countries have large child populations and their immunization programs are hampered by occasional problems with vaccine supply and inaccessibility to vulnerable populations (Haber et al. 2007).

There are also challenges as regards the management of vaccine logistics in Africa where one fifth of the countries are still expected to implement the auto disposal syringes and maintain adequate safety and wastes disposal (Machingaidze et al 2013).

2.4 Immunization Coverage in Ethiopia

The Ethiopia EPI was started in 1980 with an intention of reaching 100% coverage by 1990 (WHO: Expanded Program on Immunization). The EPI program in Ethiopia is administered by the Ministry of Health with technical support from the WHO and other organizations (Sullivan et al., 2009). International partners provide extra support in expanding coverage of EPI. For instance, the Reaching Every District (RED) approach is collaboration with the WHO, USAID, UNICEF, Global Alliance for Vaccines and Immunization (GAVI), and Centers for Disease Control (CDC) (Kidane, 2006). The RED approach consists of strengthening social mobilization activities, and developing culturally appropriate behavioral change communication strategies (Berhane,Y. 2008).

Currently Ethiopia has recorded significant reduction in childhood mortality rate by increasing child immunization coverage. The DPT3 immunization coverage reached 84.9% in 2011/12 against the target of 90%. It is estimated that increasing immunization has the second highest impact (after access to clean water) on reducing child mortality and should be prioritized during the remaining few years in order for the country to reach the MDG target by 2015 (MOFED, 2012).

2.5 Determinants of Immunization among Children

Determinants of childhood vaccination uptake still remain complex, and are dependent on various socioeconomic, demographic factors and also supply and demand factors. A multiregional study done in Malawi, Ethiopia, India, Bangladesh, and the Philippines showed that there was a very significant general demand for better quality of vaccination services (Streefland et al, 1999). Maternal characteristics, sex of child and birth order of the child, place of delivery and antenatal care (ANC) follow up, wealth index, knowledge about vaccination and place of residence could influence immunization coverage among children (New and Senior, 1991). Reasons for routine vaccination non compliance have been studied both in Ethiopia and other countries, and many of the reasons have correlations with proxy measures of social capital. Father's ability to speak English was found to be significantly associated with uptake of child vaccination in Ghana (Burgha et al., cited in Sullivan et al., 2009). Sullivan et al., found that higher maternal age was correlated to greater likelihood of vaccination completion. Decision making power of women is also associated with childhood vaccination. Male gender of child is seen to have a better effect on child outcome in many developing countries. In Ethiopia, this is not the case. Male infant mortality in Ethiopia is higher than the female infant mortality EDHS (2005). According to Kidane et al(2006), age of mother, and sex of child were not significant factors in vaccination uptake. Children of low parity households in Ethiopia were also more likely to be vaccinated than those in high parity families (Kidane et al. , 2006). Tadessa et al. (2008), in their study in southern Ethiopia found that family size, age of mother, ethnicity, religion or educational status were not associated with child immunization.

CHAPTER THREE

DATA AND METHODOLOGY

3.1 Source of Data

The source of data for the study was the 2011 Ethiopia Demographic and Health Survey (EDHS) conducted by Central Statistical Agency (CSA). It is the third survey conducted in Ethiopia as part of the worldwide Demographic and Health Surveys project. The 2011 Ethiopia Demographic and Health Survey was designed to provide estimates for the health and demographic variables of interest for the following domains: Ethiopia as a whole; urban and rural areas (each as a separate domain); and 11 geographic administrative regions (9 regions and 2 city administrations).

The principal objective of the 2011 EDHS is to provide current and reliable data on fertility and family planning behavior, child mortality, adult and maternal mortality, children"s nutritional status, use of maternal and child health services, knowledge of HIV/AIDS, and prevalence of HIV/AIDS and anaemia.

The 2007 Population and Housing Census, conducted by the CSA, provided the sampling frame from which the 2011 EDHS sample was drawn. The 2011 EDHS sample was selected using a stratified, two-stage cluster design; enumeration areas (EAs) were the sampling units for the first stage. The sample included 624 EAs, 187 in urban areas and 437 in rural areas. Households comprised the second stage of sampling. A complete listing of households was carried out in each of the 624 selected EAs from September 2010 through January 2011. A representative sample of 17,817 households was selected for the 2011 EDHS, of which 17,018 were covered during data collection. Of these, 16,702 were successfully interviewed, yielding a household response rate of 98 percent.

All women aged 15-49 and all men aged 15-59 were eligible for interview. The 2011 EDHS used three questionnaires: the Household Questionnaire, the Woman's Questionnaire, and the Man's Questionnaire. These questionnaires were adapted from model survey instruments developed for the MEASURE DHS project to reflect the population and health issues relevant to Ethiopia. In addition to English, the questionnaires were translated into three major local languages-Amharigna, Oromiffa, and Tigrigna.

In the interviewed households 17,385 eligible women were identified for individual interview; complete interviews were conducted for 16,515, yielding a response rate of 95%. Similarly, a total of 15,908 eligible men were identified for interview; completed interviews were conducted for 14,110, yielding a response rate of 89%. In general, response rates were higher in rural areas than urban areas, for both women and men.And for the analysis presented in this study, 1882 children aged 12 - 23 months captured by the data with the questions being answered by their mothers/caregiver.

3.2 Variables Considered in the Study

As demonstrated in the literature review, socio-economic and demographic characteristics are considered as the most important determinants of immunization among children aged 12 - 23 months.

3.2.1 The Response Variable

The response variable is immunization status. According to the World Health Organization (WHO), each child is expected to have completed an immunization schedule before celebrating his/her first birthday. Through this, a child is considered fully vaccinated (immunized) if he or she has received a BCG vaccination against tuberculosis, three doses of DPT, vaccine to prevent diphtheria, pertussis, and tetanus; at least three doses of polio vaccine; and one dose of measles vaccine within the first year. And partially immunized means if the child received only some of the vaccines mentioned above and not immunized means that the child did not received any vaccines. In order to meet the objective set in this study we create the following response variables.

$$\mathrm{Y_i} = \begin{cases} 1, \textit{if a child aged } 12-23 \textit{ months old has received all the recommended vaccines} \\ 2, \textit{if a child aged } 12-23 \textit{ months old only received some of the recommended vaccines} \\ 3, \textit{if a child aged } 12-23 \textit{ months old did not received any vaccines} \end{cases}$$

3.2.2 Predictor/Explanatory Variables

The predictor variables to be studied as determinants of immunization among children aged 12-23 months old in Ethiopia are listed in table 3.1 below.

Table 3.1 Description and categories of explanatory variables

Variables and Categories representation of variables	Categories
1. Sex of child	0= Female 1= Male
2. Place of Residence	0= urban 1= rural
3. Mother's Education(EDUM)	0 = No education 1 = primary 2 = secondary and higher
4. Education of husband/partner (EDUP)	0 = No education 1 = Primary education 2 = Secondary and above
5. Wealth index	0= Poor 1= Medium 2= Rich

6. Place of delivery	0= Home / and other non health facility places 1= Hospital / and other health facility places
7. Birth order of the child	0 = 1 1 = 2-3 2 = 4-5 3 = 6+
8. Possession of Radio	0 = No 1= Yes
9. Region	1=Tigray 2=Afar 3= Amhara 4=Oromiya 5=Somali 6=Ben-Gumuz 7=SNNP 8=Gambela 9=Hareri 10=Addis Ababa 11=Dire Dawa

3.3 Methodology

In this study we have employed ordinal logistic regression (Proportional Odds) model and test related are used as a general methodology.

3.3.1 Proportional Odds (PO) Model

Ordinal data are often analyzed using the Proportional Odds Model (POM). Conceptually introduced by Aitchison and Silvey in 1957, developed by Snell in 1964, and further developed and popularized by Walker and Duncan in 1967 and by McCullagh in 1980 (Aitchison and

Silvey 1957, Snell 1964, McCullagh 1980, Walker and Duncan1967). The Proportional Odds model is a popular extension of logistic regression to ordinal data (Aitchison and Silvey 1957, Snell 1964, McCullagh 1980). The motivation of the models is the existence of an underlying continuous and perhaps unobserved random variable (McCullagh 1980).

The proportional odds (PO) model, also called cumulative odds model (Agresti, 1996, 2002; McCullagh, 1980; McCullagh and Nelder, 1989, 2000) is a commonly used model for the analysis of ordinal categorical data and comes from the class of generalized linear models. It is a generalization of a binary logistic regression model when the response variable has more than two ordinal categories. It is used to estimate the odds of being at or below a particular level of the response variable.

The proportional odds model assumes that the cumulative logits can be represented as parallel linear functions of the independent variables. That is, for each cumulative logit the parameters of the models are the same, except for the intercept. Consequently, according to the proportional odds assumption, the odds ratio is the same for all categories of the response variable.

The proportional odds, however, has some appealing features. At first, it is invariant under several categories, as only the signs of the regression coefficients change. Secondly, it is invariant under collapsibility of the ordered categories, as the regression coefficients do not change when response categories are collapsed or the category definitions are changed. Thirdly, it produces the most easily interpretable regression coefficients, as $\exp(\hat{\beta})$ is the homogenous odds ratio over all cut-off points summarizing the effects of the explanatory factor X on the response Y in one single frequently used measure. Due to these reasons, the PO model is by far the most used regression model for ordinal data.

Let Y takes categorical response variable with *K* ordered categories and assume $P(Y = 1) = P_1$, $P(Y = 2) = P_2$,…, $P(Y = j) = P_j$; for j =1,2,…,K. Cumulative probabilities reflect the ordering, with $P(Y \leq 1) \leq P(Y \leq 2) \leq \cdots \leq P(Y \leq K) = 1$. And let the cumulative probability of the first of Y *is* $P(Y \leq j \mid X) = \phi_j(\mathbf{X})$, j =1, 2,…, K-1.

Then proportional odds model models the log odds of the first K-1 cumulative probabilities which is

$$\begin{aligned}
\text{logit } \mathrm{P}(\mathrm{Y} \leq \mathrm{j} \mid \mathrm{X})] &= \log\left[\frac{\mathrm{P}(\mathrm{Y} \leq \mathrm{j} \mid \mathbf{X})}{1-\mathrm{P}(\mathrm{Y} \leq \mathrm{j} \mid \mathbf{X})}\right] \\
&= \log\left[\frac{\mathrm{P}(\mathrm{Y} \leq \mathrm{j} \mid \mathbf{X})}{\mathrm{P}(\mathrm{Y} > j \mid \mathbf{X})}\right] \\
&= \log\left[\frac{\phi_{\mathrm{j}}(\mathrm{X})}{1-\phi_{\mathrm{j}}(\mathbf{X})}\right] \\
&= \log\left[\frac{\phi_1(\mathbf{X}) + \cdots + \phi_{\mathrm{j}}(\mathbf{X})}{\phi_{\mathrm{j}+1}(\mathbf{X}) + \cdots + \phi_{\mathrm{K}}(\mathbf{X})}\right] \\
&= \alpha_j + \mathbf{X}'\beta_i \\
&= \alpha_j + \textstyle\sum_i^p \beta_i X_i \quad , j = 1,2,\ldots,K-1 \text{ and } i = 1,2,\ldots,p
\end{aligned} \tag{3.1}$$

where

$P(Y \leq j \mid X) = \phi_1(\mathbf{X}) + \cdots + \phi_{\mathrm{j}}(\mathbf{X})$

$\sim_j$ term called the threshold

$\phi_1(\mathbf{X}) + \cdots + \phi_{\mathrm{k}}(\mathbf{X}) = 1$

j =1, …, K denotes the number of response categories

and *p* denote the number of explanatory variables

The above Equation (3.1) is called proportional odds model and it has the same effect of vector β for each cumulative logit. In this model, each cumulative logit has its own $\sim_j$ term called the threshold value and their values do not depend on the values of the independent variable for a particular case. The $\sim_j$ are increasing in j, since $\mathrm{P}(\mathrm{Y} \leq \mathrm{j} \,|\, \mathbf{X})$ increasing in j for fixed **X** (Agresti, 2002).

3.3.2. Estimation of Model Parameters

The maximum likelihood estimation procedure is used to obtain estimates of the model parameters. Two iterative maximum likelihood algorithms are available in SAS PROC LOGISTIC. The default is the Fisher-scoring method, which is equivalent to fitting by iteratively reweighted least squares. The alternative algorithm is the Newton-Raphson method. Both algorithms give the same parameter estimates; however, the estimated covariance matrix of the parameter estimators may differ slightly. This is due to the fact that the Fisher-scoring method is based on the expected information matrix while the Newton-Raphson method is based on the observed information matrix. For this study the Fisher scoring method is used to obtain the maximum likelihood estimate parameters.

The dependent variable (y) used in this study is the immunization status of children aged 12 -23 months with value of 1(fully immunized), 2(partially immunized) and 3(not immunized). Let $p_1 = P(y = 1)$, $p_2 = P(y = 2)$ and $p_3 = P(y = 3)$. Then the logit model has the form:

$$logit(p_1) \equiv log\left(\frac{p_1}{1-p_1}\right) = log\left(\frac{p_1}{p_2+p_3}\right) = \alpha_1 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p$$

$$logit(p_1 + p_2) \equiv log\left(\frac{p_1+p_2}{1-(p_1+p_2)}\right) = log\left(\frac{p_1+p_2}{p_3}\right) = \alpha_2 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p$$

We see that while the intercepts are different the remaining regression parameters are the same. It is easy to see that the odds become

$$\frac{p_1}{1-p_1} = e^{\alpha_1} e^{\beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p} \quad , \quad \frac{p_1 + p_2}{p_3} = e^{\alpha_2} e^{\beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p} \quad = c\left(\frac{p_1}{1-p_1}\right)$$

Where $c = \exp(\alpha_2 - \alpha_1)$. Hence the name proportional odds model implies that that odds ratios for y being fully immunized(1) versus partially immunized or not immunized (2 or 3) and y being fully immunized or partially immunized (1 or 2) versus not immunized (3), are the same.

After the parameters $\alpha_1, \alpha_2, \beta_1, \beta_2, \ldots, \beta_p$ are estimated, it is easy to compute predicted probabilities using the following formulas derived from the above equations.

$$\hat{p}_1 = \frac{e^{\hat{\alpha}_1 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \cdots + \hat{\beta}_p x_p}}{1 + e^{\hat{\alpha}_1 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \cdots + \hat{\beta}_p x_p}},$$

$$\hat{p}_1 + \hat{p}_2 = \frac{e^{\hat{\alpha}_2 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \cdots + \hat{\beta}_p x_p}}{1 + e^{\hat{\alpha}_2 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \cdots + \hat{\beta}_p x_p}} \quad \text{and}$$

$$\hat{p}_3 = 1 - (\hat{p}_1 + \hat{p}_2)$$

Logistic regression coefficients indicate the direction and strength of the relationship between independent variable and the log odds of dependent variable. However, these logistic regression coefficients are a little bit more complicated to intuitively gauge, as they present the influence of a unit change in the independent variable on the log odds of the dependent variable. The influence determines the rate of increase or decrease in the log odds of dependent variable. This means that the effect of the independent variable is the same for different logit functions, that’s also the reason why the model is called the proportional odds model.

In standard practice, the null hypothesis of equal slopes (proportional odds) is tested with the score test for proportional odds. This test is provided by most of the standard statistical packages. A statistically non-significant test is considered sufficient evidence that the proportional odds assumption was not violated. Because this test is sensitive to sample size and may be significant in cases with minimum deviation from proportionality, some authors recommend plotting the log odds generated by each cut point as a complementary analysis for proportionality of odds (Scott, Goldberg & Mayo 1997).

3.3.3 Proportional Odds (PO) Assumption

This assumption has many different names: proportional odds assumption (Wolfe and Gould, 1998), parallel regression assumption (Long and Freese, 2003), and parallel line assumption (SAS Institute, 2004; Williams, 2006). It is important that we recognize these different names and realize that they refer to the assumption that the coefficients are equal across all cut points. For this study, we will use the word " proportional odds assumption " and "parallel line assumption" interchangeably .

3.3.4 Violation of the Proportional Odds Assumption (Parallel Line Assumption)

Prior to fitting the ordered logit model, the parallel line assumption can be tested. If the assumption is not met, then at least one of the parameters differs across the ordinal categories. Violation of the parallel line assumption can lead to results being incorrect, incomplete, or misleading (Boes and Winkelmann, 2004; Williams, 2006). Among researchers, there is a general agreement that the parallel line assumption is very restrictive and is frequently violated (Long and Freese, 2003). In these cases, Long and Freese (2003) and Williams (2006) recommend that another regression model that does not impose the strict constraints of parallel regression, be considered. Suggested alternative models are multinomial logit or generalized ordered logit models such as the partial constrained ordered logit (PCOL) and the stereotype models.

If the parallel line assumption is not violated, then the ordered logit model is estimated. Of the two alternative options, the multinomial logit is the least preferred because it does not take into account ordering information, thereby rendering the model inefficient (Boes and Winkelmann, 2004). It also estimates more parameters than is necessary making the interpretation more difficult (Williams, 2006). However, the PCOL model, which is a special case of the generalized ordered logit model, can overcome these limitations. The generalized ordered logit models can estimate models that are less restrictive than ordered logit models and more parsimonious and interpretable than multinomial logit model. The PCOL model relaxes the constraints on the variables when the parallel line assumption is violated, and simultaneously retains the information obtained from the ordering of the data. In the generalized ordered logit models, there is a possibility that negative probabilities could occur. Predicted probabilities are computed to identify if any negative probabilities exist.

3.3.5 Partial Proportional Odds Model

As the proportional odds assumption is difficult to achieve in practice, the PPOM may be used as an alternative. This model allows some covariates with the proportional odds assumption to be modeled, but for those variables in which this assumption is not satisfied it is increased by a coefficient (¥), which is the effect associated with each i^{th} cumulative logit, adjusted by the other covariates. The general form of the model is the same as the PO model, but now the coefficients are associated with each category of the response variable.

Partial proportional odds model can be classified as PPOM-UR and the restricted one. The unrestricted partial proportional odds model is used when proportional chances assumption is not valid and the coefficients are associated with each category of the response variable (in the case of both parallel and linear assumption are not fulfilled).

The model has the form:

$$P(Y_i \leq j \mid X) = \frac{\exp(\alpha_j + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_{3j} x_{3i})}{1+\exp(\alpha_j + \beta_1 x_{1i}c + \beta_2 x_{2i} + \beta_{3j} x_{3i})}, \quad j = 1, 2, \ldots, K-1 \qquad (3.2)$$

where i represents the child, j is the different immunization status categories, and K is the number of immunization status categories. In the PCOL model, the parallel line assumption is relaxed for only those variables that violate the assumption; this means that some of the β's can be the same for all values of j, while other β's can differ across the different immunization status . For instance, equation (3.2) indicates that the coefficients for variables X_1 and X_2 are constant for all values of j, while X_3's coefficient can vary across the different values of j (Williams, 2006).

3.3.6 The Odds Ratio

Logistic regressions work with odds so it is necessary to define both odds and odds ratio. The odds are simply the ratio of the probabilities for the two possible outcomes. If π is the probability that the event will occur, then $1-\pi$ is the probability that the event will not occur:

$$Odds = \frac{\pi}{1-\pi} \qquad (3.3)$$

The odds ratio is a measure of association for 2×2 contingency table (Agresti, 2007). In 2×2 tables the probability of "success" is π_1 in row 1 and π_2 in row 2. Within row 1, the odds of success is defined as $odds_1 = \frac{\pi_1}{(1-\pi_1)}$ and within row 2 the odds of success equal $odds_2 = \frac{\pi_2}{(1-\pi_2)}$.

Evaritt(1998) and Agresti (2002) define the odds ratio in two groups of subjects as "the ratio of odds". Thus;

$$\theta = \frac{Odds_1}{Odds_2} = \frac{\pi_1(1-\pi_2)}{\pi_2(1-\pi_1)}$$

3.3.7 A Test of a Single Predictor

3.3.7.1 The Wald Test

The Wald test is an alternative test which is commonly used to test the significance of the individual logistic regression coefficients for each independent variable.That is, the Wald test is used to test

$H_0 : \ {}_j = 0$ against $H_0 : \ {}_j \neq 0$ j= 1,…,k

For a dichotomous independent variable, the Wald statistic (W) is

$$W = \left[\frac{\hat{\ }_j}{se(\hat{\ }_j)} \right]^2, \ j = 1,\ldots, k \qquad (3.4)$$

For large sample size this statistic has an approximate chi-square distribution with one degree of freedom under the assumption that H_0 is true.

3.3.8 Goodness of Fit of the Model

Lipsitz *et a(1996)* suggest a novel approach for testing the goodness of fit of the proportional odds models. This approach is basically an extension of the method proposed by Hosmer and Lemeshow in testing goodness of fit of logistic models for ordinal binary responses. This method is based on the notion of partitioning the subjects into groups or regions. To form the goodness of fit statistic used in this approach, firstly a score S_m is assigned to response category *m*. The assigned scores may in some instances be the actual numerical response or the midpoint of the interval when the response is crude grouping of an underlying continuous variable. When the response has no underlying numerical scale, such as a response with 3 levels : Fully immunized, Partially immunized, None immunized are often an integer score is used such as, 1= Fully immunized, 2= Partially immunized, 3= None immunized.

Then a *fitted score* or a *predicted mean score* can be defined as,

$$\hat{\text{«}}_t = \sum_{l=1}^{m} s_1 \hat{p}_{tl} \quad ; t= 1, 2, \ldots\ldots, n \qquad (3.5)$$

Where n is the number of subjects and $\hat{p}_{t1}, \hat{p}_{t2}, \ldots\ldots\ldots, \hat{p}_{tm}$ are the predicted probabilities for the t^{th} subject for the m response levels.

Then to form the goodness of fit statistic, the subjects should be partitioned or grouped into *G* regions based on the percentiles of the predicted mean scores $\hat{\text{«}}_t$. As a general rule, the value of *G should* be decided such that $6 \leq G < n/5m$. In practice, any *G* that satisfies the inequality can be used; for the Hosmer-Lemeshow statistic for binary responses, *G* = 10 has become popular.

The G regions can be partitioned such that the first group contains subjects with smallest predicted mean scores and the last group contains subjects with largest predicted mean scores. Given the partition of the data, the goodness of fit statistic is formulated by defining G–1 group indicators,

$$I_{tg} = \begin{cases} 1, if\ \hat{\text{«}}_t\ is\ in\, region\ g \\ 0, otherwise \end{cases} \qquad \text{where } g = 1, 2, \ldots, G - 1.$$

Then to assess the goodness of fit of model (3.11) the following alternative model is constructed.

$$\text{logit } \mathrm{P}(\mathrm{Y} \leq \mathrm{j} \,|\, \mathrm{X})] = \alpha_j + \sum_{i}^{p} {}_i X_i + \sum_{g=1}^{G-1} I_g \text{¥}_g \tag{3.6}$$

where g = 1, 2, …, G – 1, j = 1, 2, …K-1 and i = 1, 2, ……p

If the model (3.6) is correctly specified, then $H_0\text{: ¥}_1 = \text{¥}_2 \ldots = \text{¥}_9 = 0$ is not rejected.

3.3.1.4 Model Diagnostics

Regression model building is often an iterative and interactive process. The first model we try may prove to be inadequate. Regression diagnostics are used to detect problems with the model and suggest improvements.

There are three ways that an observation can be considered as unusual, namely outlier, influence and leverage. In logistic regression, observations whose values deviate from the expected range and produce extremely large residuals and may indicate a sample peculiarity are called **outliers**. These outliers can unduly influence the results of the analysis and lead to incorrect inferences. An observation is said to be **influential** if removing the observation substantially changes the estimate of coefficients. Influence can be thought of as the product of leverage and outliers. An observation with an extreme value on a predictor variable is called a point with high leverage.

Leverage is a measure of how far an independent variable deviates from its mean. In fact, the leverage indicates the geometric extremeness of an observation in the multi-dimensional covariate space. These leverage points can have an unusually large effect on the estimate of logistic regression coefficients (Cook, 1998).

To identify if an observation is outlier or influential, the following rules of thumb were employed in this study.

- **Residuals:** Standard and deviance residuals are obtained for each observation. Observations with values larger than 3 in absolute value are considered as outliers (Agresti, 2007).
- **Leverage Value (Hat Diagonal)** is a measure of how far an observation is from the others in terms of the levels of the independent variables (not the dependent variable). Observations with values larger than one are considered to be potentially highly influential (Belsley et al., 1980).
- **DFBETA(S)** is a diagnostic measure which measures the change in the logit coefficients for a given variable when a case is dropped. If DFBETAs is less than unity, this implies no specific impact of an observation on the coefficient of a particular predictor variable, while DFBETA of a case greater than 1.0, and implies the observation is an outlier (Cook and Weisberg, 1982).
- **Cook's D** is a measure of aggregate impact of each observation on the group of regression coefficients, as well as the group of fitted values. In logistic regression, a case is identified as influential if its Cook's distance is greater than 1.0 (Hosmer- Lemeshow, 2000).

CHAPTER FOUR

STATISTICAL DATA ANALYSIS AND RESULTS

4.1 Summary of Descriptive Statistics

A total of 1882 children between the age of 12 and 23 months were included in the study. The mean age of children is 17 months with standard deviation of 3.35. Male children accounted for 50.7% of the total children.

The major socio-economic and demographic characteristics of the respondents and children with their immunization status are presented in Table 4.1. Of the 1882 children, 1549(82.3%) of them resided in rural areas and the remaining 333(17.7%) resided in urban area. The proportion of fully immunized children differs by type of place of residence: Above 54% living in urban areas received full immunization while 23.3% residing in rural areas received full immunization.

The proportion of fully immunized children varied from one region to the other. For example, the highest proportion of fully immunized children was observed in Addis Ababa (79.2%) followed by Dire Dawa(60.5%) and Tigray (57.9%). Low proportions of fully immunized children was recorded in Afar (5.8 percent) followed by Gambela (14.3%).

The proportion of fully immunized children was varied by place of child delivery. The highest proportions of fully immunized children was observed for children whose place of delivery were in hospital and/or other health facilities places as opposed to the lowest proportion of fully immunized children was observed for children whose place of delivery is in homes and/or other non health facilities places.

The proportion of fully immunized children was varied by the household economic status. The highest proportion of fully immunized children was from rich households (43.9 %) whereas the lowest proportion of the fully immunized children (17.8 %) was recorded among children residing from poor households.

Table 4.1 Distribution of Socioeconomic and Demographic Characteristics of Child Immunization.

Variables	Level of Children Immunization Status						Total
	Fully immunized		Partially immunized		Not immunized		
	Count	%	Count	%	Count	%	
Child immunization Status	541	28.7	1028	54.6	313	16.6	1882
Sex of child							
Female	272	29.3	510	55.0	145	15.7	927
Male	269	28.2	518	54.2	168	17.6	955
Place of Residence							
rural	361	23.3	900	58.1	288	18.6	1549
urban	180	54.1	128	38.4	25	7.5	333
Mother's Education							
No education	304	23.9	693	54.6	273	21.5	1270
primary	164	33.2	293	59.3	37	7.5	494
secondary and higher	73	61.9	42	35.6	3	2.5	118
Education level of partner							
No education	215	22.9	507	54.1	215	22.9	937
Primary education	227	32.0	401	56.5	82	11.5	710
Secondary and above	99	42.1	120	51.1	16	6.8	235
Wealth index							
Poor	159	17.8	523	58.5	212	23.7	894
Medium	81	26.7	182	60.1	40	13.2	303
Rich	301	43.9	323	47.2	61	8.9	685
Place of delivery							
Home / No Health facility place	376	23.6	916	57.5	302	18.9	1594
Hospital / Health facility	165	57.3	112	38.9	11	3.8	288

Table4.1 Distribution of Socioeconomic and Demographic Characteristics of Child Immunization. (Continued)

Variables	Level of Children Immunization Status						Total
	Fully immunized		Partially immunized		Not immunized		
	Count	%	Count	%	Count	%	
Birth order of the child							
First born	118	34.3	181	52.6	45	13.1	334
Second to Third	191	30.7	344	55.2	88	14.1	623
Fourth to Fifth	121	27.7	240	54.9	76	17.4	437
Sixth and more	111	23.2	263	55.0	104	21.8	478
Possession of Radio							
No	258	22.3	683	58.9	218	18.8	1159
Yes	283	39.1	345	47.7	95	13.1	723
Region							
Tigray	114	57.9	79	40.1	4	2.0	197
Afar	10	5.8	66	38.6	95	55.6	171
Amhara	59	27.1	140	64.2	19	8.7	218
Oromiya	47	16.4	182	63.6	57	19.9	286
Somali	24	16.9	70	49.3	48	33.8	142
Ben-Gumuz	40	24.0	104	62.3	23	13.8	167
SNNP	58	23.2	161	64.4	31	12.4	250
Gambela	21	14.3	104	70.7	22	15.0	147
Hareri	38	33.6	66	58.4	9	8.0	113
Addis Ababa	61	79.2	14	18.2	2	2.6	77
Dire Dawa	69	60.5	42	36.8	3	2.6	114

4.2 Bivariate Analysis of the Explanatory Variables

In the bivariate analysis, the variables which are found to be significantly associated with immunization status of children are: place of residence of children, education of mother, education of partner/husband, wealth index, birth order of the child, place of delivery, possession of radio and region.

Table 4.2 The Bivariate Analyses of Immunization Status According to Selected Characteristics in EDHS (2011).

Variables	Level of Children Immunization Status			P-value[a]	Total respondents
	Proportion of fully immunized	proportion of partialy immunized	proportion of Not immunized		
Sex of child					
Female	29.3	55.0	15.7	0.508	927
Male	28.2	54.2	17.6		955
Place of Residence					
rural	23.3	58.1	18.6	< 0.0001	1549
urban	54.1	38.4	7.5		333
Mother's Education					
No education	23.9	54.6	21.5	< 0.0001	1270
primary	33.2	59.3	7.5		494
secondary and higher	61.9	35.6	2.5		118
Education of partner					
No education	22.9	54.1	22.9	< 0.0001	937
Primary education	32.0	56.5	11.5		710
Secondary and above	42.1	51.1	6.8		235
Wealth index					
Poor	17.8	58.5	23.7	< 0.0001	894
Medium	26.7	60.1	13.2		303
Rich	43.9	47.2	8.9		685
Place of delivery					
Home / Non Health facility	23.6	57.5	18.9	< 0.0001	1594
Hospital / Health facility	57.3	38.9	3.8		288

Birth order of the child				< 0.0001	
First born	34.3	52.6	13.1		334
Second to Third	30.7	55.2	14.1		623
Fourth to Fifth	27.7	54.9	17.4		437
Sixth and above	23.2	55.0	21.8		478
Possession of Radio				< 0.0001	
No	22.3	58.9	18.8		1159
Yes	39.1	47.7	13.1		723
Region				< 0.0001	197
Tigray	57.9	40.1	2.0		171
Afar	5.8	38.6	55.6		218
Amhara	59	64.2	8.7		286
Oromiya	27.1	64.2	8.7		142
Somali	16.4	63.6	19.9		167
Ben-Gumuz	16.9	49.3	33.8		250
SNNP	24.0	62.3	13.8		147
Gambela	23.2	64.4	12.4		113
Hareri	14.3	70.7	15.0		77
Addis Ababa	33.6	58.4	8.0		114
Dire Dawa	79.2	18.2	2.6		197

All test ware based on Pearson X^2 test of differences of proportion

4.3 Determinants of immunization: Results of Proportional Odds Model

In this study the idea behind fitting proportional odds model was to identify key determinants of full immunization among children aged 12 - 23 months old by separating children who began the vaccination schedule but did not complete it (partially immunized children) and those who did not receive any vaccination (not immunized children). A cumulative link logit model analysis with the stepwise selection procedure was performed to identify our significant variables. The statistical significance of the individual regression coefficients was tested using the Wald chi-square statistic. Accordingly, place of delivery, wealth, possession of radio and region were found to be significant predictors for immunization among child.

To select the model, here we consider AIC criterion comparison. The result based on Akaike's Information Criteria (AIC) shown in Table 4.3 suggest that the main effect model is the better model compared to the null model and interaction model since it has the smallest AIC value.

Table 4.3 Comparison of Ordinal Logistic Regression Model Based on AIC Criterion

Model	AIC
Null model	3719.175
Main effect model	3161.957
Interaction model	3171.953

4.3.1 Parameter Estimation of the Ordinal Logistic Regression

The model takes Y values: 1(Fully immunized), 2(Partially immunized), and 3(Not immunized) and assume $\phi_1(\mathbf{X}) = P(Y \leq 1)$ $\phi_2(\mathbf{X}) = P(Y \leq 2)$ and $\phi_3(\mathbf{X}) = P(Y \leq 3)$. The fitted proportional odds model of immunization status is given as follows

$$\log\left[\frac{\phi_j(\mathbf{X})}{1-\phi_j(\mathbf{X})}\right] = \alpha_j + {}_{1p}Place\_Delivery_p + \beta_{2r}Possession\ of\ Radio_r + \sum_{i=0}^{2}\beta_{3i}Wealth_i$$

$$+ \sum_{j=1}^{11} {}_{4j}REGION_j \qquad (4.1)$$

where

j = 1,2, ……., K-1

p = 0(Home/ non health facility places), 1(Hospital /Health facility places)

r = 0(No), 1(Yes)

i = 0(Poor),1(Medium), 2(Rich)

j =1(Tigray), 2(Afar), 3(Amhara), 4(Oromiya), 5(Somali) , 6(Ben-Gumuz), 7(SNNP), 8(Gambel) ,9(Harari) ,10(Addis Ababa), 11(Dire Dawa)

The above model can be rewritten as

$$\left.\begin{aligned} &\log\left[\frac{\phi_1(\mathbf{X})}{1-\phi_1(\mathbf{X})}\right] = \alpha_1 + /_{1p} Place\_Delivery_p + \beta_{2r} Possession\ of\ Radio_r + \sum_{i=0}^{2} \beta_{3i}\ Wealth_i \\ &+ \sum_{j=1}^{11} \rho_{4_j} REGION_j \quad \text{and} \\ &log\left[\frac{\phi_1(\mathbf{X})+\phi_2(\mathbf{X})}{1-\left(\phi_1(\mathbf{X})+\phi_2(\mathbf{X})\right)}\right] = \sim_2 + {}_{1p} Place_{Delivery_p} + \beta_{2r} Possession\ of\ Radio_r + \sum_{i=0}^{2} \beta_{3i}\ Wealth_i \\ &+ \sum_{j=1}^{11} {}_{4j} REGION_j \end{aligned}\right\} \quad (4.2)$$

where $\log\left[\frac{\phi_1(\mathbf{X})}{1-\phi_1(\mathbf{X})}\right]$ and $log\left[\frac{\phi_1(\mathbf{X})+\phi_2(\mathbf{X})}{1-\left(\phi_1(\mathbf{X})+\phi_2(\mathbf{X})\right)}\right]$ are the log odds for respective cumulative logit model and $\sim_1$ and $\sim_2$ are threshold values for each model respectively.

The PROC Logistic procedure of SAS is used to generate coefficients of the estimated model. Table 4.4 shows the response information of proportional odds model.

Table 4.4 Response Information of Proportional Odds Model

Ordered Value	Immunization status	Total Frequency
1	Fully immunized	541
2	Partially immunized	1028
3	Not immunized	313
Probabilities Modeled are Cumulated Over the Lower Ordered Values		

From the results of SAS output, we obtained the following regression equation consisting of the above variables:

$$\left.\begin{aligned}
&\log\left[\frac{\phi_1(\mathbf{X})}{1-\phi_1(\mathbf{X})}\right] = -1.347 + 0.882\, Place_{Delivery}{}_{1} + 0.324 Wealth_1 + 0.641\, Wealth_2 \\
&+ 0.319\ \mathrm{HHRadio}_1 + 1.19\, REGION_1 - 2.28\, REGION_2 - 0.88\, REGION_4 - 1.30\, REGION_5 - \\
&0.67\, REGION_8 + 1.094\, REGION_{10} + 1.06\, REGION_{11} \\
&\\
&log\left[\frac{\phi_1(\mathbf{X}) + \phi_2(\mathbf{X})}{1-\left(\phi_1(\mathbf{X}) + \phi_2(\mathbf{X})\right)}\right] = 1.837 + 0.882\, Place\_Delivery_1 + 0.324 Wealth_1 + 0.641\, Wealth_2 + \\
&0.319\ \mathrm{HHRadio}_1 + 1.19\, REGION_1 - 2.28\, REGION_2 - 0.88\, REGION_4 - 1.30\, REGION_5 - \\
&0.67\, REGION_8 + 1.094\, REGION_{10} + 1.06\, REGION_{11}
\end{aligned}\right\} (4.3)$$

4.3.2 Testing for Proportional Odds Model Assumption

The model (4.3) should satisfy the assumption of proportional odds to be fully accepted as a *‘proportional odds’* model. If this model fails the assumption, then other models instead of a proportional odds model should be fitted. The score test statistic for proportional odds assumption is the option in achieving the objective mentioned above. The test is designed to test the hypothesis,

H_0: The proportional odds assumption is valid

Vs

H_1: The proportional odds assumption is not valid.

The results of the score test given by the “SAS” proc logistic procedure is given in Table 4.5.

Table 4.5 Results of Score Test for the Proportional Odds Assumption

Chi-Square	DF	Pr > ChiSq
23.3969	**14**	**0.0541**

Since the p-value of the score test is 0.0542 (> 0.05), H_0 cannot be rejected at 5% significant level. Thus, the model (4.3) satisfies the proportional odds assumption and hence it is not necessary to go for another model.

Table 4.6 Summary of Stepwise Selection

Effect	DF	Wald Chi-Square	Pr > ChiSq
Place of Delivery	1	26.5786	<.0001
Wealth Index	2	26.4919	<.0001
Possession of Radio	1	8.9807	0.0027
REGION	10	330.4809	<.0001

Table 4.7 Analysis of Maximum Likelihood Estimates

Covariate	Category	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept(threshold)	Intercept-1	1	-1.3468	0.1522	78.3248	<.0001
	Intercept-2	1	1.8370	0.1582	134.8945	<.0001
Place of Delivery	Hospital/Health facil.	1	0.8219	0.1594	26.5786	<.0001
Wealth Index	medium	1	0.3239	0.1397	5.3792	0.0204
	Rich	1	0.6407	0.1254	26.1206	<.0001
Possession of Radio	Yes	1	0.3191	0.1065	8.9807	0.0027
Region	Tigray	1	1.1906	0.2036	34.1939	<.0001
	Afar	1	-2.2857	0.2167	111.2263	<.0001
	Oromiya	1	-0.8835	0.1859	22.5768	<.0001
	Amhara	1	-1.3025	0.2227	34.2091	<.0001
	Somali	1	-0.6709	0.2199	9.3105	0.0023
	Gambela	1	1.0935	0.3342	10.7050	0.0011
	Addis Ababa	1	1.0656	0.2433	19.1815	<.0001
	Dire Dawa	1	-1.3468	0.1522	78.3248	<.0001

Table 4.8 Odds Ratio Estimates

Covariate	Category	Point Estimate	95% Wald Confidence Limits	
Place of Delivery	Hospilal/Health fac. vs Home/non Health	2.275	1.664	3.109
Wealth Index	Medium vs Poor	1.382	1.051	1.818
	Rich vs Poor	1.898	1.484	2.426
Possession of Radio	Yes vs No	1.376	1.117	1.695
Region	Tigray vs Amhara	3.289	2.207	4.902
	Afar vs Amhara	0.102	0.067	0.156
	Oromiya vs Amhara	0.413	0.287	0.595
	Somali vs Amhara	0.272	0.176	0.421
	Gambela vs Amhara	0.511	0.332	0.787
	Addis Ababa vs Amhara	2.985	1.550	5.746
	Dire Dawa vs Amhara	2.903	1.802	4.676

Moreover, the overall model fit evaluates the contribution of each effect to the model. The results of Likelihood ratio, Score and Wald test for model goodness of fit displayed in table 4.9, suggests that model is well fitted to the data.

Table 4.9 Overall measures of goodness of fit of the final model: BETA=0.

Testing Global Null Hypothesis: BETA=0			
Test	**Chi-Square**	**DF**	**Pr > ChiSq**
Likelihood Ratio	585.2186	14	<.0001
Score	499.4866	14	<.0001
Wald	479.9393	14	<.0001

4.3.3 Goodness of Fit Measures

In order to assess the goodness of fit of the fitted model (model 4.1) the following alternative model is constructed.

The alternative model (see model 3.6 in chapter 3)

$$\log\left[\frac{\phi_j(\mathbf{X})}{1-\phi_j(\mathbf{X})}\right] = \alpha_j + {}_{1p}Place\_Delivery_p + \beta_{2r}HHRadio_r + \sum_{i=0}^{2} {}_{3i}Wealth_i + \sum_{j=1}^{11} \beta_{4j}REGION_j + \sum_{g=1}^{9} I_g ¥_g$$

and the fitted model (model 4.1 above):

$$\log\left[\frac{\phi_j(\mathbf{X})}{1-\phi_j(\mathbf{X})}\right] = \alpha_j + {}_{1p}Place\_Delivery_p + \beta_{2r}HHRadio_r + \sum_{i=0}^{2} {}_{3i}Wealth_i + \sum_{j=1}^{11} \beta_{4j}REGION_j$$

If the fitted model is correctly specified, then $H_0: ¥_1 = ¥_2 = \cdots = ¥_9 = 0$ is not rejected.

The alternative model was fitted using "SAS" proc logistic procedure and the testing of H_0 is carried out using the likelihood ratio, Wald and the score test statistic on the fitted model and the alternative model . By looking at the p-values of the three test results illustrated in Table 4.10, it can be concluded that the fitted model is preferable to the alternative model. The hypothesis $H_0: ¥_1 = ¥_2 = \cdots = ¥_9 = 0$ is not rejected at 5% significance level and hence, it can be concluded that the fitted model fits the data well.

Table 4.10: Results of Testing Significance of the Alternative Model against the Selected Model

Test	Model	Test Statistics	Difference in Test Statistic	Difference in D.F.	P - value
Likelihood Ratio	The fitted	585.2186	10.7010	9	0.2967
	The alternative	574.4452			
Wald	The fitted	499.4886	9.582	9	0.390
	The alternative	489.9066			
Score	The fitted	479.939	6.06	9	0.734
	The alternative	473.879			

4.3.4 Model Diagnostics for Proportional Odds Model

When the fit of a proportional odds (cumulative logit) model fit well, it also fits well with similar effects for any collapsing of the response categories. Since diagnostic for ordinal and multinomial model is very difficult, one way to examine model adequacy is to check each of the binomial models separately (Hosmer - Lemshow, 2000). Therefore, diagnostics is performed using binary outcome used for multiple logistic regression analysis, i.e. by collapsing partially immunized and not immunized into not immunized. Model diagnostics is performed for both outliers and influential points.

The diagnostic test results for detection of outliers and influential values are presented in Appendix 1. The DFBETAs for model parameters including the constant term and Cook's influence statistic were both less than unity. DFBETAs less than unity imply no specific impact of an observation on the coefficient of a particular predictor variable, while Cook's distance less than unity showed that an observation had no overall impact on the estimated vector of regression coefficients β. A value of the leverage statistic less than one shows that no subject has a substantial large impact on the predicted values of the model. And none of the observation has standard and deviance residuals larger than 3 in absolute value. The residuals less than 3 in absolute value show the absence of an outlier observation. Thus, from the above goodness of fit tests and diagnostic checking we can say that our model is adequate.

4.3.5 Interpreting the Result of Proportional Odds Model

The interpretations of the parameters corresponding to different variables which are found significant in the final model are described in the following section and comparisons are made with the reference category.

Being a residence of Tigray region, Addis Ababa and Dire Dawa increases the likelihood of being in a fully immunized category (as opposed to partially immunized or not immunized category) by 3.289 times, 2.985 times and 2.903 times respectively as compare to being a residence of Amhara region while being a residence of Afar region, Oromiya region, Somali region and Gambela region reduces the likelihood of being in the fully immunized category (as opposed to partially immunized or not immunized category) by 89.8%, 58.7%, 72.8%, and 48.9% respectively than the reference region(Amhara region). Similarly, the odds of the combined of fully immunized and partially immunized versus not immunized is 3.289 times, 2.985 times and 2.903 times higher for children in Tigray, Addis Ababa and Dire Dawa respectively compared to children in Amhara given the other variables in the model are held constant.

For children born in hospital and /or other health facility places compared to those born at home and /or other non health facility places the odds of being fully immunized versus the combined partially immunized and not immunized are 2.275 times higher given the other variables are held constant. Likewise, the odds of the combined categories of fully immunized and partially immunized versus not immunized is 2.275 times higher for children born in hospital and /or other health facility places compared to those born at home and /or other non health facility places given the other variables model are held constant in the model.

The estimated odds ratio ($\widehat{OR} = 1.376$) revealed that the odds of being in the fully immunized category (as opposed to partially immunized or not immunized category) for children who live in the household who possess radio increases by 37.6% than the reference group. Similarly, the odds of being in the fully immunized category or partially immunized category (as opposed to not immunized category) for children who live in the household who possess radio increases by 37.6% than the reference group holding all other variables constant. The 95% confidence interval also suggests that odds could be as minimum as 1.12 and as maximum as 1.69.

Wealth index have significant influences on child immunization status. Children from middle class and rich family compared to children from poor family the odds of being fully immunized (as opposed to partially or not immunized) 89.8% and 38.2% higher respectively controlling other variables model. Similarly, the odds of being fully immunized or partially immunized (as opposed to not immunize) for children from middle class and rich family 89.8% and 38.2% higher respectively compared to children from poor families, holding all other variables constant. The 95% confidence interval also suggests that odds could be as minimum as 1.05 and as maximum as 1.82 for children who from middle class family and as minimum as 1.48 and as maximum as 2.43 children from rich family.

CHAPTER FIVE

Discussion, Conclusions and Recommendations

In this chapter we discuss the main findings of this study, make a conclusion and recommendations.

5.1 Discussion

This study attempted to identify determinants of immunization among children aged 12 -23 months in Ethiopia based on Ethiopian Demographic and Health Survey (EDHS 2011) data. Accordingly descriptive analysis and proportional odds model techniques were used.

In this study a total of 1882 children were included with mean age of 17 months old and standard deviation 3.35. Among children who participated in this study 82.3% resided in rural areas. This found that 28.7% of these children were fully immunized 54.4% did not complete their recommended immunization (partially immunized) and 16.6% were not vaccinated (not immunized) at all.

This study found evidence that some of the demographic and socioeconomic variables considered had significant influence on child immunization status. The results showed that the place of delivery, wealth index , possession of radio and region were found to be important determinants of immunization among children aged 12-23 months. Based on the findings in the preceding chapter, this study arrived at the following conclusions.

The proportional odds model revealed that children that were born in hospitals and /or other health facilities places are 2.275 times the odds of being fully immunized (than partially immunized or not immunized) as compare to children born in home and /or other non health facilities places.This is in agreement with the findings in other studies. Hussen Mohammed and Alemayehu Atomsa (2013) showed that delivery in health institutions was found to be a significant factor for full immunization in children in Oromiya region, Eastern Ethiopia. Their result showed that children born in health institution were 1.98 times more likely to have fully immunization compared to those who were born in homes. The same result was found in the study conducted in Ethiopia by Kassahun Trueha and Fikre Enquoselessie (2012). Based on EDHS 2005 data, they showed that children who were born at health institutions were 0.154 times less likely to be not fully immunized than children who were born at home. Funmilayo Adebiyi (2013) also showed children born at any health facilities were 7 times [$\widehat{OR}$ =6.53] more likely to receive full immunization than children born at non health facility in Nigeria. A study from India showed that children delivered in heath institution were 2 times more likely to be fully immunized than children delivered at home (Anjali Y. and Guruswamy M., 2007).

The study showed that children from poor families were less likely to have full immunization compared to those from middle class and rich family. Result obtained by fitting proportional odds model showed that children from middle class and rich family the odds of being fully immunized (as opposed to partially or not immunized) increases by 89.8% and 38.2% respectively. The finding of our study is in agreement with the same result obtained by Bezuhan Aemro and Yibeltal Tebekaw (2013). Based on EDHS 2011 data, they found that in Ethiopia children from the richest and middle class households are less likely to be fully unimmunized by

74% and 57% respectively compared to those from the poorest households. Based on EDHS 2005 data, Kassahun Trueha and Fikre Enquoselessie (2012) and Sharmily G. Roy (2010) showed that in Ethiopian children from the richest quintile had a higher likelihood of being fully immunized than any other wealth quintile and the odd of fully immunization in children increases when the category of wealth index goes to lowest to the highest category. Lucius Donsa(2013) showed that in Malawi children from poor families are less likely to have complete vaccination status compared to those from the middle class ($\widehat{OR}$=0.930) and the rich ($\widehat{OR}$= 0.830).Funmilayo Adebiyi (2013) also showed that in Nigeria children from rich households, were 7 times ($\widehat{OR}$ =7.47) more likely to receive full immunization than children from poor household; children from a middle class household were almost 3 times ($\widehat{OR}$ =2.87) more likely to receive full immunization than children from poor household.

In this study the availability of radio in the household was found to be significantly related to better status of immunization of children.The proportional odds model analysis yielded ($\widehat{O}$R=1.376) implying that children from a household that have a radio were 37% more likely to fully immunized (as opposed to partially immunized or not immunized) compared to those children from a household that did not have radio. In Malawi children from households that own a radio had 20% higher odds of having complete vaccination status compared to those that do not have a radio Lucius Donsa (2013).

This study showed that there is an observed regional discrepancy with respect to full immunization in children aged 12-23 months in Ethiopia. As compared to the reference region namely, Amhara Region. Children in Afar, Oromiya, Somali and Gambela were less likely to complete their immunization (fully immunized). On the other hand children who lived in Addis

Ababa, Dire Dawa and Tigray region were more likely to fully immunized than those in Amhara region. A study conducted by Bezuhan Aemro and Yibeltal Tebekaw (2013) showed children from SNNP, Oromia and Amhara regional states are 3.82, 7.00 and 3.65 times more likely to be fully unimmunized compared to Tigray regional state that has the second highest proportion of fully immunized children. No significant difference was observed between Addis Ababa and Tigray regional State. And Sharmily (2010) also showed that being from any region other than the capital of Addis Ababa was also associated with not being fully vaccinated. A child from the Somali region was only 0.05% as likely to be fully vaccinated as a child from Addis Ababa.

5.2 Conclusion

The study identified that place of delivery, wealth index, possession of radio and region were found to be significant predictors of full child immunization among children aged 12-23 months old in Ethiopia.

5.3 Recommendations

The findings of this study have policy implications regarding full immunization among children aged 12-23 months old in Ethiopia. The findings need to be converted into development of adequate interventions that aim to increase full immunization in children.

- The government or concerned bodies should give special attention to those regions with low child immunization such as Afar and Gambela regions.
- Efforts should be made to improve place of child delivery of women both in urban and rural areas of Ethiopia.
- Vaccines should be available all time in health institutions giving vaccination service with appropriate storage materials.
- The government should take action to support the very poor, and to bring about rapid national economic growth. To this effect, it is important to develop community-based interventions giving priority to very poor households to participate in the child vaccination

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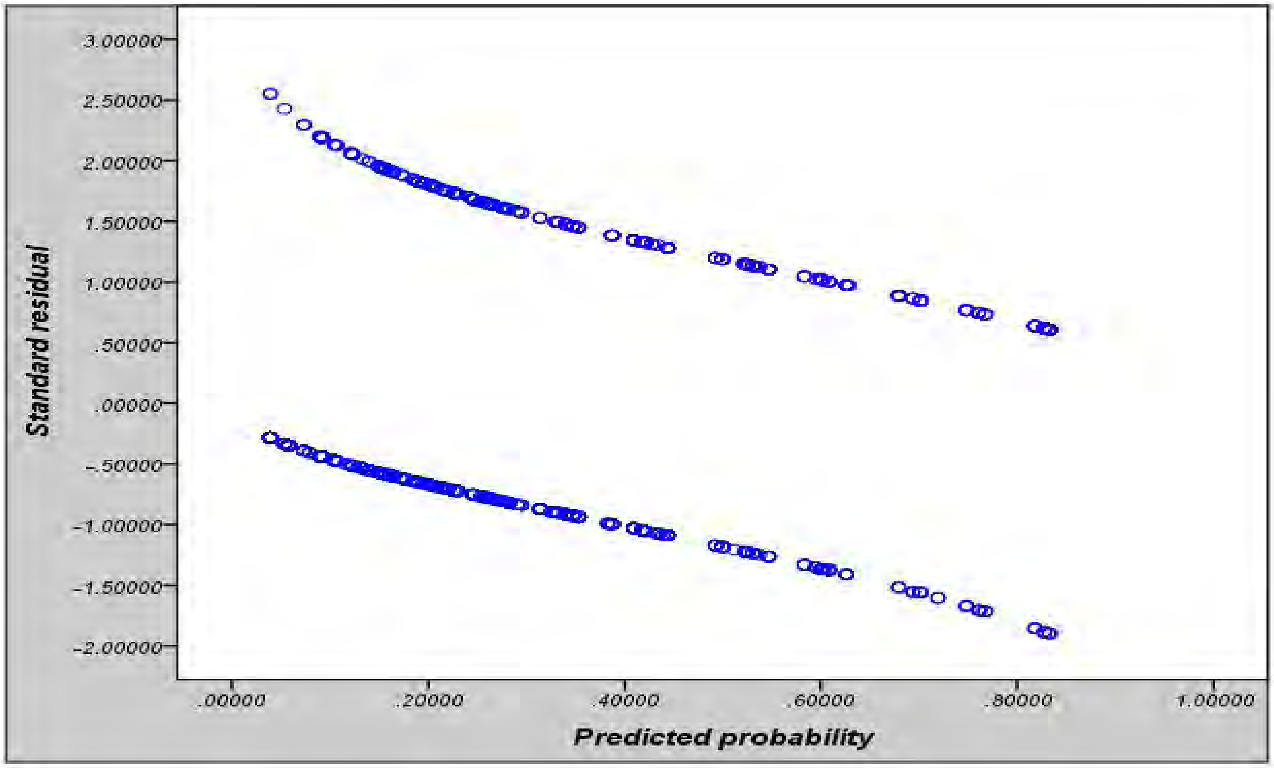
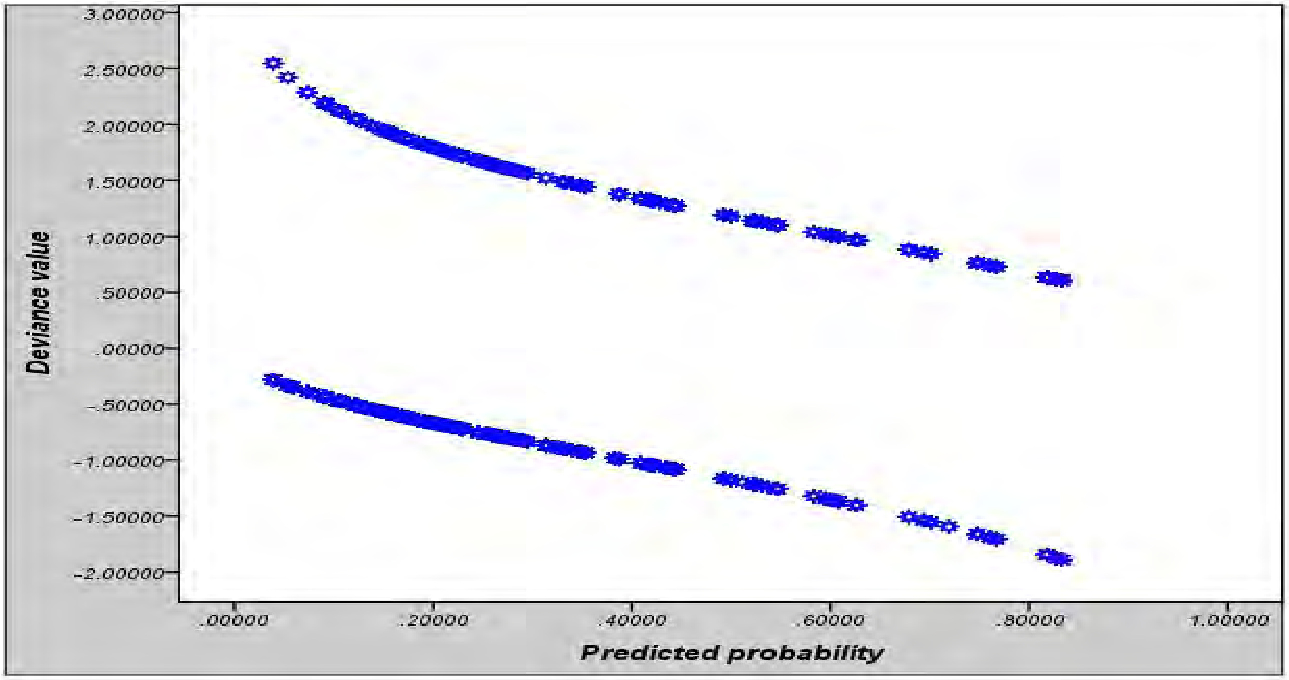
Appendixes

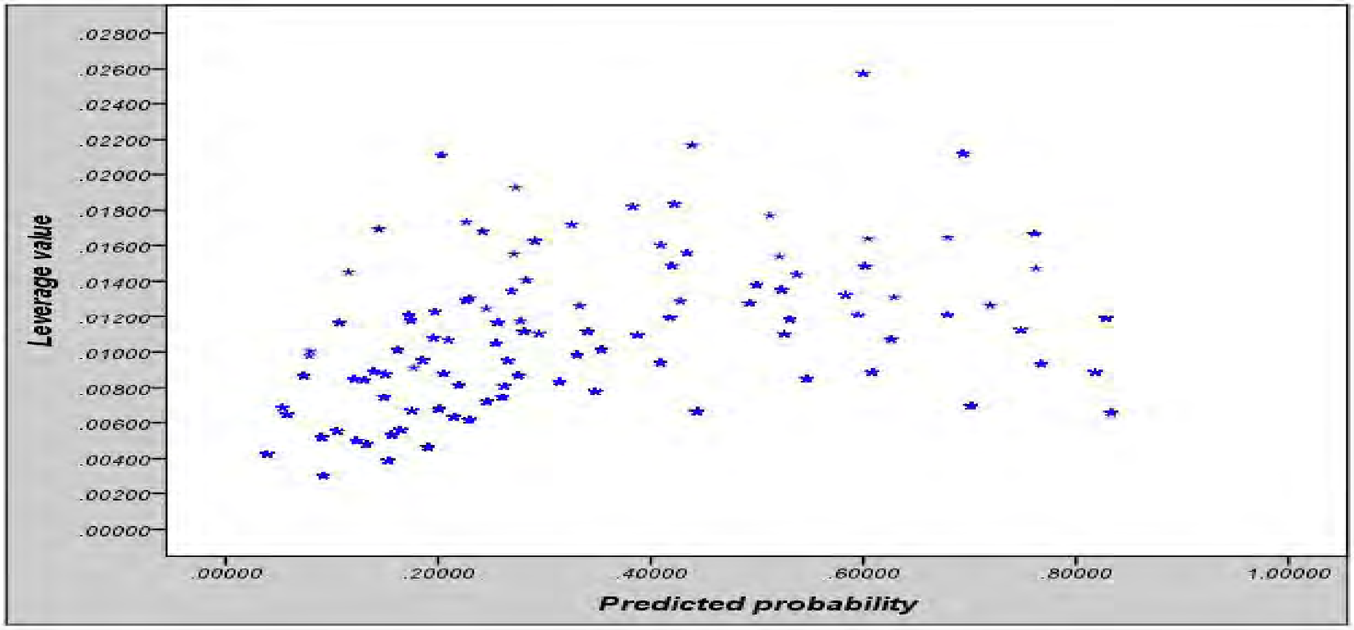
Appendix 1: Results of Diagnostic Tests for Outliers and Influential Value for Standard logistic regression Descriptive statistics of model diagnosis

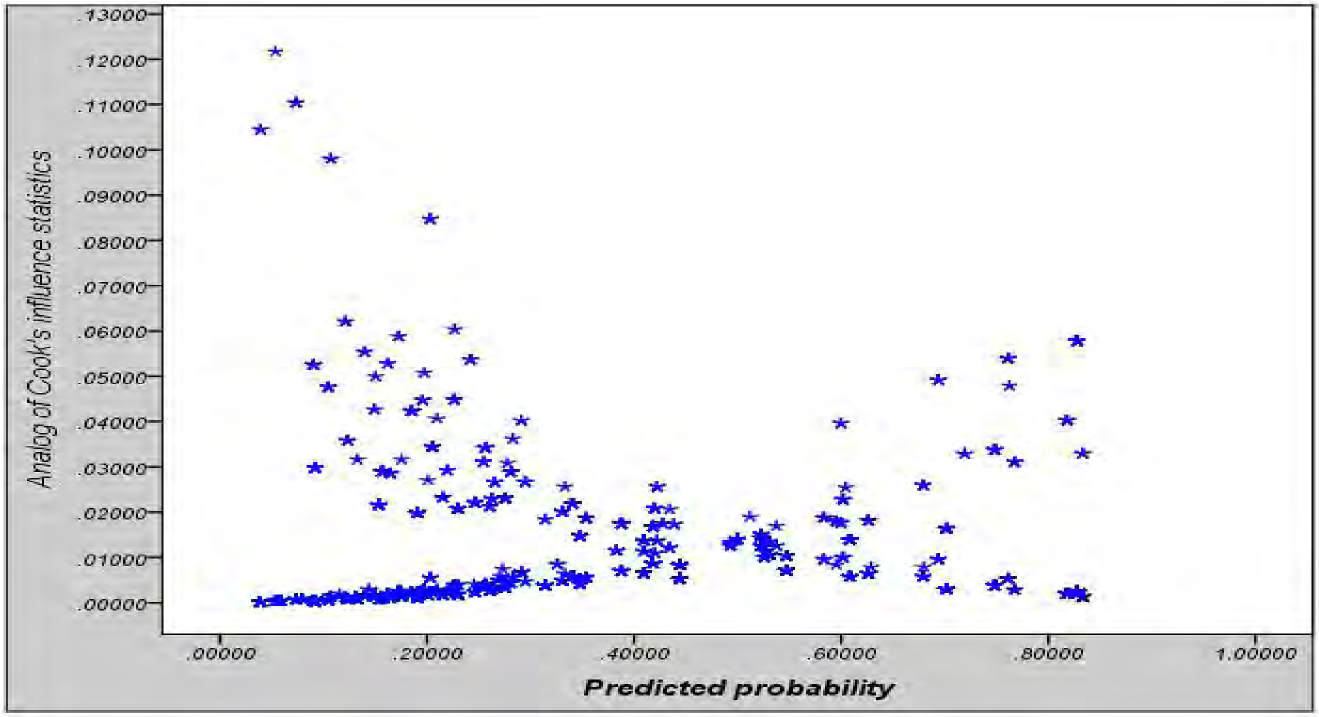
Table 4.11 Descriptive Statistics of DFBETAS

	N	Minimum	Maximum
DFBETA for constant	1882	-.02814	.02883
DFBETA for Wealth(1)	1882	-.01286	.02456
DFBETA for Wealth(2)	1882	-.01483	.01739
DFBETA for Place_Delivery(1)	1882	-.02091	.02107
DFBETA for HHRadio(1)	1882	-.01028	.01096
DFBETA for REGION(1)	1882	-.02563	.03194
DFBETA for REGION(2)	1882	-.02601	.11047
DFBETA for REGION(3)	1882	-.02488	.03098
DFBETA for REGION(4)	1882	-.02397	.03385
DFBETA for REGION(5)	1882	-.02488	.04929
DFBETA for REGION(6)	1882	-.02499	.03227
DFBETA for REGION(7)	1882	-.02490	.03209
DFBETA for REGION(8)	1882	-.02515	.05503
DFBETA for REGION(9)	1882	-.02246	.04086
DFBETA for REGION(10)	1882	-.06513	.04463
Valid N (listwise)	1882		


3.00000
2.50000
2.00000
1.50000
1.00000
.50000
.00000
-.50000
-1.00000
-1.50000
-2.00000
Standard residual
.00000
.20000
.40000
.60000
.80000
1.00000
Predicted probability


3.00000
2.50000
2.00000
1.50000
1.00000
.50000
.00000
-.50000
-1.00000
-1.50000
-2.00000
Deviance value
.00000
.20000
.40000
.60000
.80000
1.00000
Predicted probability


.02800
.02600
.02400
.02200
.02000
.01800
.01600
.01400
.01200
.01000
.00800
.00600
.00400
.00200
.00000
Leverage value
.00000
.20000
.40000
.60000
.80000
1.00000
Predicted probability


.13000
.12000
.11000
.10000
.09000
.08000
.07000
.06000
.05000
.04000
.03000
.02000
.01000
.00000
Analog of Cook's influence statistics
.00000
.20000
.40000
.60000
.80000
1.00000
Predicted probability

Appendix 2: SAS Codes

```
title ’Ordinal Main effects model’;
Proc logistic data =SASUSER.IMMUNIZATION;
Class  Place_Delivery(ref='0') Wealth(ref='0') HHRadio(ref='0')  REGION(ref='3')
/param= ref order = internal;
model  Complete_vaccination =Place_Delivery Wealth HHRadio REGION  /link = clogit;
format Place_Delivery Wealth HHRadio Region ;
run;

title ’Ordinal Interaction effects model’;
Proc logistic data =SASUSER.IMMUNIZATION;
Class  Place_Delivery(ref='0') Wealth(ref='0') HHRadio(ref='0')  REGION(ref='3')
/param= ref order = internal;
model  Complete_vaccination =Place_Delivery Wealth HHRadio REGION
Place_Delivery*HHRadio Wealth*HHRadio  REGION*HHRadio/link = clogit scale = none
aggregate;
format Place_Delivery Wealth Radio Region  ;
run;

title ’Goodness of Fit for Proportional Odds Model’;
/* Formulating predicted mean scores and Indicator variables
to separate the subjects into 10 regions */
data goodnes;
/*import data*/
set SASUSER.IMMUNIZATION;
/*import the predicted probabilities of the fitted model*/
set pred;
/*defining the 9 indicator variables*/
I1=0; I2=0; I3=0; I4=0; I5=0; I6=0; I7=0; I8=0; I9=0;
g=1882/10;
/*calculation of predicted mean score (m) from predicted
probabilities*/
m=(1*ip_1)+(2*ip_2)+(3*ip_3);
proc sort data=goodnes;
by m;
run;

data good;
set goodnes;
i=_n_;
/*Grouping the 1882 subjects into 10 regions by using the 9
indicator variables*/
if i<=g then I1=1;
else if i<=2*g then I2=1;
else if i<=3*g then I3=1;
else if i<=4*g then I4=1;
else if i<=5*g then I5=1;
else if i<=6*g then I6=1;
else if i<=7*g then I7=1;
else if i<=8*g then I8=1;
else if i<=9*g then I9=1;
/*Fitting the alternative model [Model-(M*)]*/
proc logistic data=good;
```

```
class Place_Delivery Wealth HHRadio REGION I1-I9/param= ref order = internal ;
model Complete_vaccination=Place_Delivery Wealth HHRadio REGION I1-I9/link = clogit
scale = none aggregate;
run;
data good
set goodnes;
i=_n_;
/*defining a single indicator variable that separates the subjects
into 10 regions*/
if i<=g then I=1;
else if i<=2*g then I=2;
else if i<=3*g then I=3;
else if i<=4*g then I=4;
else if i<=5*g then I=5;
else if i<=6*g then I=6;
else if i<=7*g then I=7;
else if i<=8*g then I=8;
else if i<=9*g then I=9;
else if i<=10*g then I=10;

proc sort data=good;
by I Complete_vaccination;
run;
```