Modelling of the highest level of children’s education in the family using Multilevel Ordinal Logistic Regression Analysis

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Abstract. Multilevel ordinal logistic regression analysis is a type of regression that modelling data with hierarchical structure and has an ordinal response variable. The Indonesian Family Life Survey (IFLS) produced data with hierarchical structure from individuals nested within sub-district. This research had three goals: first, to select the best model of the highest level of children’s education in the family; second, to explain factors that affecting the highest level of children’s education; third, to describe the characteristics of the highest level of children’s education categories. The result showed that the best model was the random intercept model. The estimation variance of between sub-districts was 0.2314. The explanatory variables that have significant effects in the model were mother's education, number of household members, and number of household members who graduated from senior high school and status of residence. People who had high probability to go to university were coming from family which the mother had at least senior high school background, most of family member graduated from senior high school, and they lived in Bogor city. In the other hand, people who had high probability to had only elementary school were coming from family which the mother had elementary school background, no members of family who graduated from senior high school, and they lived in Bogor Regency.

1. Introduction

Education is one of human resources quality indicators, the better education shows the better human resources quality. Generally, there are two factors that affecting education, individual factors and environmental factors. Individual factors include physic condition and psychologist conditions such as intelligence which measured by IQ, motivation, and others. Environmental factors include family environment, school environment, society environment and living environment.

According to Indonesian Central Bureau of Statistics (BPS) data in 2014, Bogor City and Bogor Regency are part of West Java areas, which had high population density and population growth rate. However, school participation number (APS) aged 7-12 years in Bogor Regency and Bogor city are lower than another areas. Therefore, we need an analysis to select the best model and to explain factors that affecting the level of education.

Indonesian Family Life Survey (IFLS) is longitudinal survey in Indonesia with the smallest unit is household. This survey used multistage sampling design and produced data with hierarchical structure. In data with hierarchical structure, individuals in the same group tend to be similar to each other. The individual observations are in general completely dependent [1]. Therefore, we require multilevel analysis to modelling data with hierarchical structure. Multilevel model is a linear mixed model involves a mix of fixed effects and random effects. Groups in the hierarchical structure are assumed as
random effects that have distribution. In multilevel model, explanatory variables can be defined at any level of the hierarchy.

One of variables were observed in IFLS is the highest level of children’s education in the family. That variable is an ordinal response variable. Based on previous research that used multilevel regression [2], there was diversity among sub-districts in scores of children’s education level. This research used the fifth IFLS data of Bogor Regency and Bogor city to select the best model and to explain factors that affecting the highest level of children’s education in the family. The used method is multilevel ordinal logistic regression analysis with individuals (children) as the first level and sub-district as the second level. Maena [3] also used the same method in final value data of Statistics Method, Faculty of Mathematics and Natural Sciences IPB where students (first level) nested within parallel class (second level).

In this paper, IFLS are described in section 2 while basic definitions of Ordinal regression are out in section 3. In section 4, basic definitions of multilevel ordinal logistic regression are described. Meanwhile, the used data are described in section 5 and the used method is described in Section 6. Then, the results are discussed in Section 7.

2. Indonesian Family Life Survey
Indonesian Family Life Survey (IFLS) is a socio-economic longitudinal survey in Indonesia. Family life survey are a set of detailed household and community surveys of developing countries conducted by the RAND Corporation, in collaboration with research institutions in the given countries. The currently available country surveys cover Malaysia, Indonesia, Guatemala and Bangladesh. IFLS provide data at the individual and family level. The sample is representative of about 83% of the Indonesian population living at 13 provinces in Sumatra, Java, Bali, West Nusa Tenggara, Kalimantan and Sulawesi. The IFLS sampling scheme stratified on provinces, then randomly sampled within provinces. The IFLS was based on the sample frame used in national socioeconomic survey (SUSENAS) that designed by Indonesian Central Bureau of Statistics (BPS).

IFLS has been implemented 5 times since 1993. The first wave was conducted in 1993 by RAND in collaboration with Demography Institution, University of Indonesia. Then the second wave was conducted in 1997 by RAND in collaboration with UCLA and Demography Institution, University of Indonesia. The third wave was conducted in 2000 by RAND in collaboration with the Population Research Centre, Gadjah Mada University. Then the fourth wave was conducted in 2007 by RAND in collaboration with Survey Meter and Centre for Population and Policy Studies, Gadjah Mada University. The fifth wave was fielded 2014 by RAND in collaboration with Survey Meter.

3. Ordinal Logistic Regression Analysis
Ordinal logistic regression is a type of regression that modelling data which has an ordinal response variable with other numerical or categorical explanatory variables. Suppose that $Y$ is an ordinal response variable with $C$ category. $x' = (x_1, x_2, ..., x_p)$ is explanatory variable vector. Then the probability of $c$-category at value $x$ can be expressed by $P[Y = c \mid x] = \pi_c(x)$ and the cumulative probabilities is [3]:

$$P[Y \leq c \mid x] = \pi_1(x) + ... + \pi_c(x)$$

The cumulative logits models are defined as:

$$L_c(x) = \log \left( \frac{P[Y \leq c \mid x]}{1-P[Y \leq c \mid x]} \right)$$

$$= \log \left( \frac{\pi_1(x) + ... + \pi_c(x)}{\pi_{c+1}(x) + ... + \pi_C(x)} \right)$$

$$= \alpha_c + x'\beta$$

with $c = 1, ..., C-1$ and $\alpha_c = \alpha_1, ..., \alpha_{C-1}$ are threshold model and $\beta$ is regression coefficient vector. The used parameter estimation method in this model is maximum likelihood method. This method assumes that observations are independent to each other [5].
4. Multilevel Ordinal Logistic Regression Analysis

Data with an ordinal response variable and hierarchical structure can be modelled using multilevel ordinal logistic regression analysis. According to Hedeker[6] suppose that there are \( C \) categories of ordinal response variable and vector explanatory variables \( x^t = (x_1, x_2, ..., x_p) \), then the probability of a response at value \( x \) can be expressed by \( P[Y_{ij} = l \mid x] = \pi_{ijl}(x) \) and the cumulative probabilities are defined as:

\[
P_{ijc} = P(Y_{ij} \leq c \mid x) = \sum_{l=1}^{c} \pi_{ijl}(x)
\]

with \( l = 1, 2, ..., c ; c = 1, 2, ..., C-1 \).

Multilevel logistic model for the cumulative probabilities is given in terms of the cumulative logits as:

\[
\text{logit} \left( P(Y_{ij} \leq c \mid x) \right) = \log \left[ \frac{P_{ijc}}{1-P_{ijc}} \right] = \gamma_c + [x'_{ij}\beta + v_j]
\]

with \( i = 1, 2, ..., n_j ; j = 1, 2, ..., k ; c = 1, 2, ..., C-1 \); whereas \( n_j \) is number of individuals in \( j \)-group, and \( k \) is number of groups. \( \beta \) is vector of regression coefficient and \( v_j \) is random effect in the second level which assumed to \( N(0, \sigma_v^2) \). The used parameters estimation method in this model is maximum likelihood method with iteration [6].

5. Materials

The used data in this research are the fifth IFLS data of Bogor Regency and Bogor City, and data of village potency (PODES) in 2014. The fifth IFLS in Bogor Regency was conducted in 147 households across 27 of 40 sub-districts. Meanwhile, the fifth IFLS in Bogor City was conducted in 145 households across 6 sub-districts. This research only used data with certain criteria, 287 children across 16 sub-districts in Bogor Regency and 6 sub-districts in Bogor City. Figure 1 shows the data structure in this research.

![Figure 1 The data structure in this research](image)

Ordinal response variable in this research is the highest level of children’s education in the family. That variable was divided into 4 categories: elementary school, junior high school, senior high school and university. The explanatory variables defined at two levels. At the first level, these included:

1. gender \((X1)\)
   - 0 = male; 1 = female
2. father’s education \((X2)\)
   - 1 = elementary school; 2 = junior high school; 3 = senior high school; 4 = university
3. mother’s education \((X3)\)
   - 1 = elementary school; 2 = junior high school; 3 = senior high school; 4 = university
4. parent’s monthly income \((X4)\)
   - 1 : income < 1500000
   - 2 : 1500000 \leq income < 2500000
   - 3 : income \geq 2500000
   - 4 : missing values
5. number of household members \((X5)\)
6. number of household members who graduated from senior high school \((X6)\)
At the second level, variables included:
1. status of residence \((X_7)\)
   \(1 = \text{regency}; 2 = \text{city}\)
2. number of senior high school in sub-district \((X_8)\)
3. main jobs of people in sub-district \((X_9)\)
   \(1 = \text{agricultural}; 2 = \text{non-agricultural}\)

6. Methods
The steps of data analysis in this research are as follows:
1. IFLS data processing
   Select individuals who had status as child, finished the school and lived in Bogor Regency or Bogor City. Then select the used variables that described in previous section.
2. PODES data processing
   Take data at sub-district level in Bogor Regency and Bogor City.
3. Combine IFLS data and Podes data
4. Analyse data with descriptive analysis to know characteristics of the data
5. Select the best model with the following steps [1]:
   a. Select fixed effects structure
      i. build model without explanatory variables
      ii. build model by adding explanatory variables at the first level
      iii. build model by adding all of explanatory variables
   b. select random slopes structure by adding random effect of each first-level explanatory variables
   c. add interaction between the second-level explanatory variable with the first-level explanatory variable having a significant random slope coefficient
   d. build the final model by reducing the variables that haven’t significant effect
      Compare models using deviance or likelihood ratio test (LRTs).
      \[ D = -2 \log \left( \frac{L_{\text{nested}}}{L_{\text{full}}} \right) \]
      with \(L_{\text{nested}}\) is value of probability function in nested model and \(L_{\text{full}}\) is value of probability function in full model. The alternative hypothesis used is the full model was better. Distribution of \(D\) is Chi-squares, which degrees of freedom equal to the difference in the number of parameters between two compared models.
6. interpret coefficients using odds ratios
7. find the classification accuracy of the final model
8. explain characteristics of the highest level of children’s education.

7. Result and Discussion
7.1. Descriptive Analysis
Percentage of the highest level of children’s education can be seen in Figure 2. Most of children in Bogor Regency and Bogor City had senior high school as the highest level of education. Comparison of percentage of highest education level between Bogor Regency and Bogor City can be seen in Figure 3. Percentage of children with elementary school as the highest level of education in Bogor Regency is higher than Bogor City whereas percentage of children with university as the highest level of education in Bogor Regency is lower than Bogor City. This shows that the highest level of children’s education in Bogor City tend to be better than Bogor Regency.
Description of the highest level of children’s education for each sub-district in Bogor Regency and Bogor City can be seen in Table 1. There was a difference of children’s percentage in each education category among sub-districts. Citeureup, Rumpin, and Cigudeg had the highest percentage of elementary school level whereas the percentage of university level is lower than other sub-districts. It shows that there was variance of the highest level of children’s education between sub-districts in Bogor Regency and Bogor City.

The main job of people in Bogor City is non-agricultural while in Bogor District are agricultural and non-agricultural. The education backgrounds of parents are mostly elementary school, but the percentage of parents with elementary school background in Bogor Regency is higher than Bogor City. It shows education background of parents in Bogor City tend to be better. Percentage of parents with high income in Bogor City is higher than Bogor Regency. It can be caused by the main job of people in Bogor City is non-agricultural.

Table 1 Percentage of highest education level for each sub-district

| Sub-districts | Number of children (%) |   |   |   |
|---------------|------------------------|---|---|---|
|               | ES         | JHS       | SHS     | University |
| Cigombong     | 0.00       | 0.00      | 100.00  | 0.00        |
| Ciawi         | 0.00       | 33.33     | 66.67   | 0.00        |
| Sukaraja      | 0.00       | 20.00     | 80.00   | 0.00        |
| Cileungsi     | 20.00      | 40.00     | 20.00   | 20.00       |
| Gunung Putri  | 0.00       | 0.00      | 100.00  | 0.00        |
| Citeureup     | 100.00     | 0.00      | 0.00    | 0.00        |
Table 1 continued Percentage of highest education level for each sub-district

| Sub-districts | Number of children (%) |   |   |   |
|---------------|------------------------|---|---|---|
|               | ES         | JHS      | SHS      | University |
| Bojong Gede   | 0.00       | 25.00    | 75.00    | 0.00       |
| Kemang        | 0.00       | 0.00     | 100.00   | 0.00       |
| Ranca Bungur  | 0.00       | 0.00     | 66.67    | 33.33      |
| Rumpin        | 75.00      | 25.00    | 0.00     | 0.00       |
| Cigudeg       | 64.38      | 17.81    | 10.96    | 6.85       |
| Tenjo         | 0.00       | 100.00   | 0.00     | 0.00       |
| Parung Panjang| 0.00       | 0.00     | 100.00   | 0.00       |
| Cibungbulang  | 0.00       | 100.00   | 0.00     | 0.00       |
| Ciampea       | 0.00       | 0.00     | 100.00   | 0.00       |
| Dramaga       | 0.00       | 0.00     | 100.00   | 0.00       |
| Bogor City    |            |          |          |            |
| South Bogor   | 0.00       | 0.00     | 40.00    | 60.00      |
| East Bogor    | 13.79      | 20.69    | 48.28    | 17.24      |
| North Bogor   | 15.09      | 22.64    | 45.28    | 16.98      |
| Central Bogor | 19.51      | 36.59    | 39.02    | 4.88       |
| West Bogor    | 12.50      | 0.00     | 50.00    | 37.50      |
| Tanah Sareal  | 0.00       | 26.92    | 50.00    | 23.08      |

7.2. Multilevel Ordinal Logistic Regression Analysis

Multilevel ordinal logistic regression required several steps, selected random intercept model, selected random slope model, and selected the best model. The used parameters estimation method in this research is maximum likelihood method.

In selection of fixed effects required several steps, build the following models:

1. Random intercept model without explanatory variable (Model 1).
2. Random intercept model with all explanatory variables at individuals level (Model 2).
3. Random intercept model with one of explanatory variables at sub-districts level (Model 3).
4. Random intercept model with all explanatory variables at sub-districts level (Model 4).

In building process of Model 3, the selected variable at sub-district level is status of residence. The variable was selected because it provided smaller log likelihood value than other variables at sub-districts level. To select the best random intercept model then compared the models. The comparison used deviance value with Chi Squares distribution. The result of comparison test can be seen in Table 2.

Table 2 The result of comparison test in building process of random intercept model

|               | -2 log likelihood | Deviance | p value |
|---------------|-------------------|----------|---------|
| Model 1       | 684.75            |          |         |
| Model 2       | 484.18            | 200.57   | 0.0000  |
| Model 3       | 479.90            | 4.28     | 0.0386  |
| Model 4       | 477.49            | 2.41     | 0.2997  |
Model 1 and Model 2 had a significant difference with p value less than 0.05 that means Model 2 is better than Model 1. Further, Model 2 and Model 3 also had a significant difference that means Model 3 is better than Model 2. Model 3 and model 4 had not significant differences with p value greater than 0.05. Therefore, the best random intercept model is Model 3, random intercept model with all of the first level explanatory variables and one of the second level explanatory variable (status of residence).

After obtain the best random intercept model then build random slopes model by adding random slopes effect. In selection of random effect structures, a random effect of each first-level explanatory variables was added in the best random intercept model, as following models:
1. Model with only random intercept (Model 1).
2. Model with random intercept and random slope of gender (M 2-1).
3. Model with random intercept and random slope of father’s education (M 2-2).
4. Model with random intercept and random slope of mother’s education (M 2-3).
5. Model with random intercept and random slope of parent’s income (M 2-4).
6. Model with random intercept and random slope of number of household members (M 2-5).
7. Model with random intercept and random slope of number of household members who graduated from senior high school (M 2-6).

The result of comparison test can be seen in Table 3. There was not random slope effects which gave significant difference to the model, so the better model is random intercept model (Model 1) which is random intercept model with all of the first level explanatory variables and one of the second level explanatory variable (status of residence). The result of parameters estimation can be seen in Table 3.

Table 3 The result of comparison test in selecting random slope effects

| Model 1 with M 2-1 | Deviance | p-value |
|-------------------|----------|---------|
| Model 1 with M 2-2 | 0.85     | 0.6538  |
| Model 1 with M 2-3 | 0.00     | 1.0000  |
| Model 1 with M 2-4 | 2.38     | 0.3042  |
| Model 1 with M 2-5 | 1.31     | 0.5194  |
| Model 1 with M 2-6 | 0.00     | 1.0000  |

Based on Table 4, there were explanatory variables that have not significant effect, there are gender, father’s education and parent’s income. Therefore, reduction on random intercept model was conducted by getting out some explanatory variables giving small effect. The result of parameters estimation can be seen in Table 5. All of the variables have significant effect to the highest level of children’s education in the family. Based on Table 5, the last model is below:

\[ L_c(x) = \beta_{0j} + 1.4272 X_3(1) + 2.0675 X_3(2) + 0.2925 X_5 - 1.0015 X_6 \]

with \( \beta_{0j} = y_c + 0.9339 X_7(1) + v_j \)

The comparison category in the highest level of children's education and the mother's education is the category of university. The comparison category in status of residence is city. The increasing intercept value from the element school category (1) to the senior high school category (3) indicates the model was cumulative logit model.
Table 4 The result of parameters estimation on random intercept model

|                | Estimated | Standard Error | P value |
|----------------|-----------|----------------|---------|
| Intercept 1    | -3.6184   | 0.7557         | 0.0001  |
| Intercept 2    | -1.6039   | 0.7367         | 0.0416  |
| Intercept 3    | 2.4245    | 0.7325         | 0.0035  |
| X1 : 1         | -0.3682   | 0.2622         | 0.1616  |
| X2 : 1         | -0.1909   | 0.6247         | 0.7602  |
| X2 : 2         | -0.8691   | 0.5880         | 0.1406  |
| X3 : 1         | 1.1138    | 0.7158         | 0.1210  |
| X3 : 2         | 2.1932    | 0.6354         | 0.0007  |
| X4 : 4         | 0.8359    | 0.5447         | 0.1261  |
| X4 : 1         | 0.8064    | 0.5365         | 0.1341  |
| X4 : 2         | 0.4689    | 0.6250         | 0.4538  |
| X5             | 0.2900    | 0.0613         | <0.0001 |
| X6             | -1.0882   | 0.1160         | <0.0001 |
| X7 : 1         | 0.9037    | 0.4196         | 0.0322  |
| νj             | 0.2680    |                |         |

Table 5 The result of parameters estimation on the final model

|                | Estimated | Standard Error | P value |
|----------------|-----------|----------------|---------|
| Intercept 1    | -3.7589   | 0.6740         | <0.0001 |
| Intercept 2    | -1.8134   | 0.6602         | 0.0124  |
| Intercept 3    | 2.1800    | 0.6528         | 0.0033  |
| X3 : 1         | 1.4272    | 0.5379         | 0.0085  |
| X3 : 2         | 2.0675    | 0.5742         | 0.0004  |
| X5             | 0.2925    | 0.0573         | <0.0001 |
| X6             | -1.0015   | 0.1033         | <0.0001 |
| X7 : 1         | 0.9339    | 0.3993         | 0.0201  |
| νj             | 0.2314    |                |         |

The cumulative probabilities for each of the highest level of children’s education can be obtained from final model by the following equation:

\[ P(Y \leq c | x) = \frac{1}{1 + \exp(-L_c(x))} \quad (c = 1, 2, 3) \]

The probability for each of the highest levels of children’s education can be calculated from the cumulative probabilities.

Positive coefficient regression in status of residence shows that children who lived in Bogor Regency tend to have lower education level. Positive coefficient regression in mother’s education indicates that children with lower mother’s education tend to have lower education level. Positive coefficient regression in number of household members indicates that children with the more household members tend to have lower education level while negative coefficient regression in number of household members who graduate from senior high school indicates that children with the
more household members who graduated from senior high school tend to have higher education level. The final model shows the intercept variance between sub-districts with number of variability is 0.2314. This is accordance with description data that there was variance of the highest level of children’s education between sub-districts.

Intercept estimation from each sub-districts are show in Table 6. Negative values of random intercept coefficients indicate that children tend to have higher chance of completing better education. Negative value in Cigudeg accordance with the description data that children in this sub-district tend to have lower level of education. This is indicated by the large percentage of children in the elementary school and junior high school categories. While in Dramaga, the percentage of children in elementary school and senior junior high category is low. Similar to South Bogor, negative value of intercept is accordance with the description data where the percentage in senior high school and university category is greater than others sub districts.

**Table 6 Intercept estimation**

| Kecamatan     | Estimated | Kecamatan     | Estimated |
|---------------|-----------|---------------|-----------|
| Cigombong     | -0.0851   | Tenjo         | 0.0795    |
| Ciawi         | -0.2733   | Parung Panjang| -0.0777   |
| Sukaraja      | 0.3465    | Cibungbulang  | -0.1455   |
| Cileungsi     | -0.0232   | Ciampea       | 0.0960    |
| Gunung Putri  | 0.0342    | Dramaga       | -0.0001   |
| Cinteureup    | 0.2868    | Bogor Selatan | -0.4688   |
| Bojong Gede   | -0.1830   | Bogor Timur   | 0.3158    |
| Kemang        | -0.0883   | Bogor Utara   | 0.6578    |
| Ranca Bungur  | -0.3050   | Bogor Tengah  | 0.0414    |
| Rumpin        | 0.0760    | Bogor Barat   | -0.2147   |
| Cigudeg       | 0.2421    | Tanah Sareal  | -0.3304   |

The accuracy of final model can be seen in Table 7. Percentage of accuracy on final model is 65.85%. Most of children are classified to senior high school category. That accordance with data description, most of children in Bogor District and Bogor City had senior high school as the highest-level education. Error classifications tend to lower education level categories because one of factors that affecting the level of education is mother's education. Children with better mother's education will have better highest education level. However, in this research, most of mothers had low education level.

**Table 7 Percentage of accuracy on final model**

|          | Estimated |                  |          |                  |          |          |
|----------|-----------|------------------|----------|------------------|----------|----------|
|          | ES        | JHS              | SHS      | University       |          |          |
| ES       | 56        | 19               | 3        | 0                | 71.79    |
| JHS      | 15        | 30               | 18       | 0                | 47.62    |
| SHS      | 2         | 15               | 89       | 5                | 80.18    |
| University| 0        | 0                | 21       | 14               | 40.00    |
| Total percentage | 65.85 |

7.3. Interpretation of Coefficients

Interpretation of coefficients in ordinal logistic regression model uses the odds ratio value. Odds ratio of final model is shown in Table 8. Based on Table 7, with 95% confidence level can be explained that
children lived in Bogor Regency will have tendency to get lower education level 1.159 to 5.586 times greater than children lived in Bogor City.

A child with mother’s education is elementary school will have tendency to finish lower education 1.445 to 12.018 times greater than children with mother that have higher education level. If number of household members increase by one unit, the tendency of children to finish lower education will increase 1.197 to 1.500 times. If number of household members who graduated from senior high school increase by one unit, the tendency of children to finish lower education will decrease 0.300 to 0.450 times.

Table 8 The result of odds ratio estimated on final model

| Variables | Odds ratio estimated | CL 95% for odds ratio |
|-----------|----------------------|-----------------------|
| X₃: 1     | 4.167                | 1.445 12.018          |
| X₃: 2     | 7.905                | 2.552 24.486          |
| X₅        | 1.340                | 1.197 1.500           |
| X₆        | 0.367                | 0.300 0.450           |
| X₇: 1     | 2.544                | 1.159 5.586           |

7.4. Characteristics of the Highest Level of Child Education Category

Each of the highest levels of child's education has certain characteristics. Children who had high probability to go to university were coming from family, which the mother had at least senior high school background, most of family member graduated from senior high school, and they lived in Bogor city. In the other hand, children who had high probability to had only elementary school were coming from family which the mother had elementary school background, no members of family who graduated from senior high school, and they lived in Bogor residence. Children who had high probability to go to junior high school were coming from family which the mother had elementary or junior high school background, household members who graduated from senior high school as much as 1 or 2, and they lived in Bogor City. Children who had high probability to go to senior high school were coming from family, which the mother had elementary, junior or senior high school background, household members who graduated from senior high school more than 3, and they lived in Bogor City.

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