Implementing Analysis of Ordinal Regression Model on Student's Feedback Response

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***Abstract*—Instruction is a multidimensional procedure including a quantity of features, for example, tutor qualities, that occasionally are hard to assess. In certain points, education efficiency, that is a part of instructing, is affected by a combination of teacher features, for example, capacity and clarity to encourage the students to make them study of his subjects, capacity to establish the lesson also with trainings and lectures. These aspects are not only attributable to motivate students but also age, gender, and prior experiences. As more and more the effectiveness of teaching is becoming even more significant in school evaluation system, it is, indeed, essential to discover how to assess it and find the significant related factors for giving the best rank of feedback to their tutors. This paper focuses the assessment of teaching effectiveness forum from students' perspective "Feedback," examines the questionnaires provided to the students of Cihan University at the end of their courses, and discovers the most effected teacher's characteristics. The outcome variable (student's feedback) was recorded on well-ordered, 5-point scale of Likert provided by the students, to a set of independent variables to teacher level. The major techniques elaborated in the model fitting for ordinal regression were stating which independent variables are most likely to be kept in the model and selecting the link function such as logit link, complementary log-log link, negative log-log link, and probit link which verified the model suitability. Further to that, several statistical diagnoses have conducted such as the model fitting, classification accuracy, and the validity assumptions of the model, which are parallel lines, were fundamentally calculated in choosing the best fitted model. The dataset implemented in the analysis entails of almost 21,566 respondents to the formed questionnaire in relation to courses of Cihan University for the 2018–2019 academic year.**

***Keywords*—Generalized linear model, Ordinal regression model, Student's feedback.**

I. Introduction

Teaching is defined as complex process and sometimes is very hard to assess since it comprises a numeral individual directions or instructor's characteristics (Arreola, 1995; Centra, 1979; Boex, 2000). To reach highly level of teaching effectiveness, a combination of instructors attributes such as ability to encourage students, clarity, capability of preparing, and organizing lectures along with exercises is not only effective but also age, gender, previous experience of teaching, and so on are needed to be taken into consideration regardless other external factors such as physical characteristics of the schoolroom or laboratory (very full or with lacking number of available computers) and class attributes for instance students' attributes; age, origin of high school, gender, mark achieved at the end of obligatory school, faculty studied by the student, size of class…, etc.

With considering the above argument, teaching is a complex process and due to surrounding student's study with several issues creates obstacle to measure its effectiveness is always a debate. Due to multidimensional teaching nature, it cannot be detected by on individual measure, for example, a comprehensive effectiveness assessment (Marsh, 1987). Marsh used factor analysis discovered nine distinct teaching dimensions (passion, education, association, group collaboration, individual affinity, scope of attention, examination/classifying, projects, and capability). As a result of his study, he reached to summarize that all nine factors have their own importance in the process of teaching and to evaluate the instructors, they are vital to be considered. On the other hand, with regard to Abrami (1989) point of view, the nature of teaching effectiveness might vary across other dimensions such as courses, instructors, students, and systems.

Substantial literature on multilevel models have been used to estimate the effectiveness of education, or in general, public segment actions, as mentioned in Goldstein (1997),

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Goldstein and Spiegelhalter (1996), and Aitkin and Longford (1986), but it looks that there is no attempt to assess instructor's effectiveness in the previous studies using these methods.

In this research, to analysis the data and reach to our objective, the ordinal regression techniques were computed to model association with the ordinal outcome, ranking ("student's feedback").Therefore, as our respondent variable is ordinal five Likert point, for example, different level of student's attitude "Feedback" toward to overall teacher's performance in the application of end course's student's feedback concern at Cihan University, and the independent variables related to teacher's demographics and other attributes relevant to their career as shown in Figure 1. It is unlikely to report normality and variance homogeneity for the ordered outcome variable. Hence, the ordinal regression model does not concern neither normality nor constant variance. However, it does require parallel lines assumption across all categorical outcome levels. Furthermore, the covariate variables considered are eight variables, age, gender, experience, qualification, academic title, full/part-time status, nationality, and type of faculties teaching. Plus, there are 12 questions related to teacher's performance as students measured based on their point of views, and here, we are going to model the following the overall feedback.

Similar other regression models, the ordinal regression technique enables researchers to discover the relationship between explanatory variables that contribute the changes of student's feedback toward to teacher's performance. The ordinal regression is also capable of estimating the level of teacher's effectiveness attributes on the outcome variable. The major challenge of modeling is to select the most effective explanatory variables which need to be kept in the model and here in the ordinal regression model is to also select the link function such as logit link, complementary log-log link, and probit link since it has directly influence to the outcome. Hales and Chakavorty (2006) and Staus (2008) all discussed this topic in their study. The principal concentration of this paper was to formulate the ordinal regression model, ordinal regression analysis usage, and the result interpretations. The students' feedback questionnaire was then examined by the ordinal regression method to gain the main three study purposes:

1. To detect substantial independent variables that affected the overall teacher's performance
2. To estimate regression coefficients along with thresholds (constant)
3. To define the direction as well as magnitude of the association between the independent variables and the overall teacher's performance named dependent variable based on the sign (+ and -) of regression coefficients.

The definitive objective of this work was to brand endorsements to boost the responsiveness of the perceptions, and the skills of teacher as suitable in the view point of research outcomes. Thus, first, we consider a binary dependent variable *y*, and to make the discussion easy, we focus just a single explanatory variable *x* (binary or continuous). Cox and Snell (1989) stated that one can investigate whether *x* influences *y*. As known the binary variable only has two values (y=1=yes or y=0=no) and the primary analysis is to examine whether an event probability $\pi(x)=P(y=1|X=x)$ is linked with by means of an suitable model. The generalized linear models in this case are provided as follows;

$$f[\pi(x)]=\alpha+\beta x \quad (1)$$

Where, f is the function (reported as link function), α is the intercept of the model, and β is the coefficient of x. Likewise, when m≥2 independent variables $x_1,x_2,x_3,\ldots,x_m$, linear combination of $\beta_1 x_1+\beta_2 x_2+\beta_3 x_3+...+\beta_m x_m$ replaces. In the light of link function usage, the below two widely link function have been considered in the analysis of binary and ordinal response variable;

1- The logit link: $f(\pi)=\log[\pi(1-\pi)]$
2- The complementary log-log link: $f(\pi)=\log[-log(1-\pi)]$

II. Categorical Ordinal Model

If *y* is considered to a categorical ordered outcome variable with $k+1$ ordered level of categories where

$$\pi_j(x)=P(Y=j|X) \quad (2)$$

Roles as the realized probability of $Y=j, j=0,1,2,\ldots,k$ and the cumulative probabilities is given by the below formula;

$$\gamma_j(x)=P(Y=j|X) \quad (3)$$

Therefore, the ordinal model is found by the generalized linear model in which the cumulative probabilities are computed as an alternative of π

$$f[\gamma_j(x)]=\alpha_j+\beta_x, j=1,2,3,\ldots,k \quad (4)$$

It is important to note that for the selecting link function *f*, the equivalent coefficients are identical for each cutoff level *j*. The appropriateness of this equal slope's assumption has to be estimated wisely before applying this model for any purpose.

The usage of link functions such as logit and complementary log-log link needs to be specified when fit models in analysis of ordinal regression since no straightforward tool to distinguish the preference of using them. In the meanwhile, for ordered data when categories are evenly distributed among all levels, the logit link is commonly suitable for analyzing. Whereas, in the presence of higher categories more probable, the complementary log-log link function can be mostly preferable to examine (Bender and Benner, 2000).

The ordinal regression model in the form of applying logit link may be written as follows;

$$f\left[\gamma_j(x)\right]=log\left\{\frac{\gamma_j(x)}{1-\gamma_j(x)}\right\}=\alpha_j+\beta x, j=1,2,3,\ldots,k \quad (5)$$

And

$$\gamma_j(x)=\frac{e^{\alpha_j+\beta X}}{1+e^{\alpha_j+\beta X}} \quad (6)$$

Where, j states the cut-off points for all groups k of the response variable. In the case of applying multiple independent variables to the ordinal regression fit, βX is substituted by the linear combination of $\beta_1 x_1+\beta_2 x_2+\beta_3 x_3+...+\beta_p x_p$. The $f[\gamma_j(x)]$ is considered as the link function that links the organized components. The α_j denotes a threshold for each cumulative probability. The estimating method of the threshold and regression coefficients is the means of the maximum likelihood which more detail can be found in the studies of Long (2003), Bender and Benner (2000), and Winship and Mare (1984).

1. The instructor's attributes are explored using descriptive statistics from the university data collected at the end of academic year
2. Two kinds of multilevel models are fitted using as response variables where the indicators are stated at point 1.

III. Methodology

The data were used from a survey provided to students from ending each course to determine how successful teaching is. The questionnaire form is specified into two sections: The first part was to collect students' characteristics information such as gender, age, and so on; the second collects information on the teacher's characteristics (instructor's teaching skills, materials, and so on); the second set of questions includes 12 general questions about teacher attributes (instructor teaching qualities, tools used), as well as a final global question about course instructor satisfaction. The answer is graded on a 5-point scale ranging from 1 (not at all satisfactory) to 5 (extremely satisfactory) (very satisfactory). The data set was collected from all stages of students as well as all departments for 201 instructors. The data are analyzed using R and SPSS v25.

The main decisions elaborated in building the ordinal regression models where determining what predictor variables had more influence on the response variable and picking the link functions that are more suitable to fit the model. Many link functions are available which are conversion of the cumulative probabilities that permit the model estimation. The below are summarized of the five link functions in Table 1.

IV. Results of the Study

Several main points should be considered when construct an ordinal regression model. First, the response variable is needed to be identified. Second, selecting of which predictors to be in the model is essential to simplify the interpretation. Least but not last, using the appropriate link function is the fundamental stage to have good fits for the data in constructing the ordinal regression model. Here, R as well as SPSS software was used. We created histogram graph to examine the nature of response variable distribution to select the best appropriate link function. Most of the cases are in upper levels of response variable categories (4 and 5) related to satisfied and strongly satisfied as given in Fig. 2. Consequently, complementary log-log has been used.

First of all, it is worth mentioning some aspects of the data in terms of gender, age, academic level, and so on. The data were collected from 19 departments running actively in the university. The highest figure goes to accounting department as in total for all stages, there were 3533 active students, while the lowest one is community health department with only 81 students for all stages. There were two shifts available for students to study (daytime and nighttime). Of course, daytime shift is much higher than night shift with 82% while the nighttime shift only had 18% students in total.

TABLE I
Types of link functions

Function	Formula	Typical implementation
Logit	$f(x)=\log(x/(1-x))$	Evenly distributed categories
Probit	$F^{-1}(x)$	Normally distributed variable
Negative log-log	$-\log(-\log(x))$	Higher probability of low categories
Complementary log-log	$\log(-\log(1-x))$	Higher probability of high categories
Cauchit (inverse Cauchy)	$\tan(\pi(x-0.5))$	Many extreme values

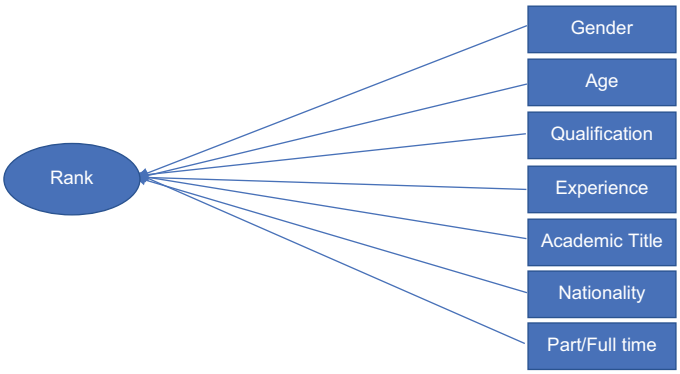

Fig. 1: Factors affecting rank.

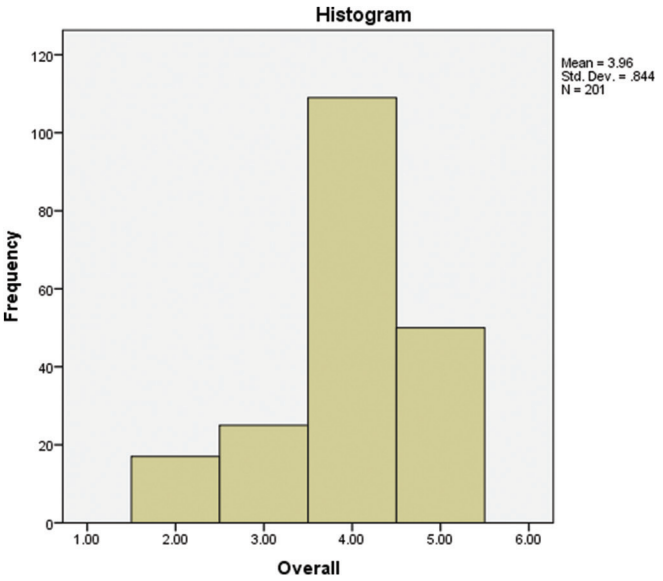

Fig. 2: The distribution of response variable.

The adequate prediction of the model must be approved before arguing the significance or importance of individual explanatory variables as provided in Table 2.

The result of Chi-square statistical test shows that there is a significant progress of including the predictors comparing to the only included intercept in the model. This basically means that having the model with involving the predictors provides better predictions.

In building statistical models, the goodness of fit is essential. Table 3 covers Pearson's Chi-square test statistic for the fitted model and the deviance. They show whether observed data and the predicted values are consisted, and since the p-values are much larger than the significant level (0.05), we failed to reject the null hypothesis says they are consisted. Therefore, we have a good model.

As known, to evaluate the fitted regression model, there is a term called coefficient of determination (R^2) which concludes the variance proportion of respondent variable associated with the explanatory variables, with greater proportion revealing that more variation is described by the model. In our case, as the dependent variable is categorical with more than 2 values, it is not ideal to calculate a sole (R^2) statistic that covers all the attributes of (R^2) in the linear regression model. Thus, the below techniques as provided in Table 4 are utilized to estimate the coefficient of determination. In the context of Cox and Snell (1989), the term of (R^2) is calculated based on the log likelihood among the models. Nevertheless, for categorical response, a theoretical maximum value of <1 is considered for "ideal" model even. The adjusted version of Cox and Snell (R^2) is widely used instead called Nagelkerke, detail can be found in Nagelkerke (1991). Like normal (R^2) it is ranged from 0 to 1. (R^2) is another measure calculated based on the log-likelihood between the intercept-only model and the full estimated model. Basically, the model with the greatest (R^2) statistic is correspondent to the "best."

We shall look at Table 5 of parameter estimates. The model confirms that there are systematic effects in receiving high positive feedback from students related to age, experience, academic title, nationality, and to department group. Respecting to age, the coefficient value is −0.109. To make the interpretation simpler, the exponent of the coefficients is taken to get the OR: Exp (−0.109) = 0.89, which explains that odds of giving higher positive feedback decrease by 0.89 for each unit increase in AGE of the lecturer.

Furthermore, a strong association can be seen between experience of working and receiving feedback, even after

TABLE II
Model fitting information

Model	−2 log likelihood	Chi-square	df	Sig.
Intercept only	454.383			
Final	398.342	56.041	10	0.000

TABLE III
Goodness-of-fit test result

Test method	Chi-square	Df	Sig.
Pearson	554.700	557	0.520
Deviance	393.608	557	1.000

TABLE IV
Technique of evaluating the model

Techniques	Value
Cox and Snell	0.243
Nagelkerke	0.271
McFadden	0.122

TABLE V
Parameter estimation result for the full model

Parameters	Estimate	Std. error	Wald	df	Sig.	95% confidence interval	
						Lower bound	Upper bound
Threshold							
[Overall = 2.00]	−6.608	0.757	76.283	1	0.000	−8.090	−5.125
[Overall = 3.00]	−5.504	0.716	59.094	1	0.000	−6.908	−4.101
[Overall = 4.00]	−3.374	0.629	28.743	1	0.000	−4.607	−2.140
Location							
Age	−0.109	0.016	45.415	1	0.000	−0.141	−0.078
Experience	0.064	0.020	10.862	1	0.001	0.026	0.103
[Gender=.00]	−0.386	0.277	1.938	1	0.164	−0.929	0.157
[Gender=1.00]	0[a]			0			
[Academic_Title=.00]	1.037	0.632	2.695	1	0.101	−0.201	2.275
[Academic_Title=1.00]	0.540	0.483	1.253	1	0.263	−0.406	1.486
[Academic_Title=2.00]	0.342	0.424	0.649	1	0.420	−0.490	1.173
[Academic_Title=3.00]	0[a]			0			
[Contract=0.00]	−0.239	0.202	1.394	1	0.238	−0.635	0.157
[Contract=1.00]	0[a]			0			
[Nationality=0.00]	0.158	0.295	0.287	1	0.592	−0.420	0.736
[Nationality=1.00]	0[a]			0			
[Depart=.00]	0.411	0.189	4.743	1	0.029	0.041	0.780
[Depart=1.00]	0[a]			0			
[Qualification=.00]	0.229	0.389	0.345	1	0.557	−0.534	0.991
[Qualification=1.00]	0[a]			0			

TABLE VI
Test of parallel lines

Model	−2 log likelihood	Chi-square	Df	Sig.
Null hypothesis	398.342			
General	386.994	11.348[c]	20	0.937

other explanatory variables have been set aside. It has a positive impact on increasing the logit of odds ratio with value 0.064, which means that with one unit increase of years' experience, the teacher is 1.066 times more likely to receive higher positive feedback from students.

There can also be seen significant and positive coefficient for department where the teacher serves. Similarly, we take the exponent of the logits to get OR, so for instance, the odds of receiving high feedback scientific department (Depart=0) are exp (0.411) = 1.501 times more than those teach in humanitarian department (reference category). The odds for lectures who hold Prof academic title are 2.82 times more likely to receive higher positive feedback than who hold Ass. Lecture title. However, the coefficients are all non-significant.

One primary assumption of using an ordinal regression model is to pass parallel test. The test basically detects whether the parameters have the same contribution for all categories in response variable. We are looking to have the approximate model with a single set of coefficients for all categories. We are looking to have the approximate model with a single set of coefficients for all categories is compared to a model with a different set of coefficients for each category in this test. Table 6 shows that the expectation is met for this issue, despite the fact that the observed significant level is extremely low. Thus, the null hypothesis can be accepted.

V. Conclusion and Recommendation

We reached to a conclusion that having student feedback system is very important to improve and develop the teacher's level of teaching and learning. Based on the data, there are some essential significant attributes of instructors which are led to satisfy students at the end of year. For instance, age of the coaches, it of course plays key role in receiving high positive feedback. The odds of receiving higher rank by an elderly instructor are 0.89. In addition, experience was also proved to be significant, the more experience of any instructor has, the higher rank of feedback is provided to. This means that with one unit increase of years' experience, the teacher is 1.066 times more likely to receive higher positive feedback from students.

It is worth mentioning department was resulted in increasing the logit odds of predicting the probability of being instructors in the top based student's feedback. The result showed that the lecturers who were teaching students at scientific department were more likely to be provided higher positive rates than those in humanitarian department with 1.501 times. Moreover, we have also put other factors in the model, but it seemed they were not statistically significant.

To popularize the model to be used for prediction, other potential attributes need to be taken into consideration such as physical aspects of the classroom or laboratory such as very crowded with an insufficient number of equipment such as computers and scientific needs and class characteristics (such as students' characteristics, high school of origin, mark obtained at the end of high school, faculty attended by the student, or size of class). These daintily have influence on quality of transmitting the usefulness of lectures to students or might be attributable to satisfy the students.

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