Quaderni di Statistica
Vol. 12, 2010

Modelling approaches for ordinal data: the case of Orientation Service evaluation

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Summary: Customer satisfaction is generally measured by means of ordinal data collected by surveys and this approach has been also pursued by University of Naples Federico II for evaluating Orientation Service offered to students disseminated throughout 13 Faculties in a broad area around the city of Naples. Monitoring of such service during several years provided a large data set, clustered in five waves and some preliminary studies have been already obtained. In this paper we examine a special class of mixture models for the statistical analysis of such information in order to infer on the relevant constructs that move answers and distinguish the students' satisfaction towards the submitted items with respect to space, time and circumstances.

Keywords: Students' satisfaction, CUB models, University Orientation Service

1. Introduction

Customer satisfaction is generally measured by means of ordinal data collected by surveys and this approach has been also pursued by University of Naples Federico II for evaluating Orientation Service offered to students in 13 Faculties disseminated in a broad area around the city of Naples. Most of the results of these studies have been monitored and verified by means of exploratory data analysis and the main results have been published in the final reports, diffused on-line under the name *VER Project* (for details: Capecchi, 2002, 2003, 2004; Iannario, 2007, 2008b).

These surveys have been organized in five waves spanning over the period 2002-2008 and several aspects have maintained throughout, as sampling methods, variables of stratification, location and modality of collecting data, type of items to test for satisfaction. Sample size has been almost doubled over the years; thus, the survey involved from 2.5% up to 5% of population of enrolled students of University of Naples Federico II. Indeed these percentages have to be considered very high if we focus on active students (students that take at least one exam within the academic year). After a long scrutiny aimed at inducing homogeneity in the collected data, 15450 questionnaires have been validated for further statistical analysis.

Since respondents change over time we cannot consider our observation as panel data. Instead, the target of the population is well characterized since users of Orientation Service strongly depends on the composition of the enrolled students of a Faculty (with reference to gender, age, job condition, and so on). In few cases, also the composition of the staff offering the service has been modified during the period.

Given the nature of the submitted items and the typology of respondents, some preliminary issues should be addressed:

- In the last decades, in Italy, we registered an uninterrupted process of reforming University by introducing new rules, curricula and criteria for monitoring graduate studies. This circumstance generated an increasing demand for help for organizing studies, selecting curricula and pursuing a correct introduction to job market. These aspects raised the importance and usage of University Orientation Service in favour of students, mostly those penalized by age, job condition, residence, study breaks, socio-economic status, and so on.
- Orientation Services offer a multifacet series of supports generally defined as pre-, *in itinere* and post- University enrollment. It is not a surprise that such variety of demand stems from different motivations in the responses and also that it cannot be considered homogeneous among Faculties. Indeed, difficulties in the studies require different skills and motivations and also job opportunities are quite different.
- Orientation Services link people of similar characteristics in one-to-one informal relationship and this circumstance produces strong

empathy between users and staff (generally, a young post-graduate in charge of front-office) that modifies formal objectives of the Orientation Service and transforms it into a more general counselling office.

- Our purpose is to investigate how statistical models are able to capture the main latent structure moving satisfaction during the years and among the Faculties. Thus, we will not enhance different compositions of such clusters since we will insert them as covariates (of subjects and/or context) to explain the observed variability of responses.

These points modify predicted results and clarify some relationships we will find in this paper. However, since we are not authorized to label Faculties except with a number, this limitation precludes further interesting and comparative considerations.

Considered as a unique research, we are faced with data coming from repeated surveys and, in this respect, they offer a substantial homogeneity with respect to declared intentions. Statistical methods should check this claim and offer interpretation of significant difference with respect to space, time and circumstances. More specifically, we will look for statistical models able to catch modifications among subjects' opinions and related to their characteristics and Faculties.

In addition to standard multivariate analysis, several methodological approaches might be pursued for this kind of data:

- Data are organized in frequency distributions of ratings with respects to items, Faculties, waves and it seems quite natural to apply multiple correspondence methods (Greenacre, 1983, 2007).
- We intend to compare the whole distribution of responses for 5 (at least) items over 13 Faculties and during 5 time waves. This kind of data may be fruitfully analyzed with methods of multi-way analysis (Kroonenberg, 2008).
- Respondents are grouped into Faculties and all data refer to waves. These groups may be correctly defined as "cluster" and thus advanced studies about hierarchical structures as multilevel models (Goldstein, 1999; Grilli and Rampichini, 2007a, 2007b) should be considered.

Our approach is different since it focusses on ordinal responses considered as a realization of a psychological process whose stochastic mechanism the research should investigate by relating subjects' evaluation to personal and environmental characteristics. We limit ourselves to examine a peculiar class of models oriented to studying ordered data arising from a satisfaction survey.

The paper is organized as follows: in section 2, we discuss the structure of data and in section 3 we explore the main features of such information by stressing the main characterizations of respondents with respect to waves. In section 4, we present CUB models as a convenient class for pursuing comparative analyses on data inclusive of variables of stratification. In section 5, we apply CUB model to generate an overview of responses by considering both waves and Faculties, for each item. Since objectives of Orientation Services include support to people that move among Faculties during their studies, section 6 is devoted to the study of such characteristics and to the effect on the expressed satisfaction. Thus, age turns out to be a relevant covariate able to discriminate different patterns among respondents and section 7 deepens this aspect by considering both interpretative and predictive power of this covariate. Finally, in section 8 we consider the indecision manifested by respondents and exploit the ability of CUB models to quantify uncertainty related to the expressed satisfaction in a more objective manner. Some concluding remarks end the paper.

2. Structure of data

Data set we have been concerned about are the result of a large experimental design and consisted of sample information stratified with respect to Faculty, Gender, Day of the week and Office hours. The format of questionnaire has been substantially unchanged during all the subsequent waves. An *a posteriori* check confirmed that proportions of selected students for interviews in different subgroups have been substantially consistent with expected proportions in the strata.

If and only if the sampled student has been an user of the Orientation Service, he/she has been asked to give a score for expressing his/her satisfaction with respect to various aspects of the Orientation Service (eight items have been investigated). Opinions with regard to satisfaction have been expressed by using an ordinal scale ranging from 1 (="completely unsatisfied") to 7 (="completely satisfied").

Questionnaires have been filled anonymously and are composed by two sections: the first one concerns information about respondent characteristics (Gender, Age, Attendance, Frequency of Service, Diploma of admission, Full-time position, Change of Faculty, Residence, Job condition) whereas the second one consists of questions related to respondents' satisfaction towards 5 items: *Information*, *Willingness*, *Opening Hours*, *Competence* and *Global* satisfaction. Indeed, for waves IV and V, three more items have been added with reference to *Usefulness*, *Structure* and *Advertising* of the Service. In this paper, we opted not to consider such further items; instead, more refined analyses for data set of the 2007 survey have been examined elsewhere (Iannario, 2008b; Corduas *et al.*, 2009).

In order to pursue an homogeneous analysis throughout the paper, we have considered, for each wave, only the subjects' covariates Gender, Frequency-of-Service, Diploma, Residence and Age, together with the expressed satisfactions as responses to questions concerning the items *Information*, *Willingness*, *Opening Hours*, *Competence*, and *Global*.

To be more specific, the subjects' covariates have been codified as follows:

- *Gender* is a dichotomous variable, with values 1 for women and 0 for men.
- *Frequency-of-Service* is dichotomous, with values 1 for regular and frequent users of the Service and 0 for the others.
- *Diploma* is a dichotomous variable, with values 1 for students possessing classic or scientific high-school qualification and 0 for the others.
- *Residence* is a dichotomous variable, with values 1 for users living in the city or the province of Naples (that is, the metropolitan area) and 0 for the others.
- *Age* is considered a continuous variable. In fact, it is recorded as an integer but given the large range of values (from 17 or 18 years up

to 60 or 70, for instance) it is fairly consistent with the assumption of continuity.

Thanks to this homogeneous structure, if we add a further column that assumes codes I-V for the five waves, respectively, the final and complete information set consists of a data frame with 15450 rows and the following 13 columns: (1) *Faculty*, (2) *Frequency-of-Service*, (3) *Age*, (4) *Gender* (5) *Diploma*, (6) *Residence*, (7) *Change-of-Faculty*, (8) *Information*, (9) *Willingness*, (10) *Opening Hours*, (11) *Competence*, (12) *Global*, (13) *Wave*. All the statistical analyses in this paper will be based on this matrix of data.

3. An exploratory study

Some preliminary information about the selected data set are presented in Table 1. Dimension and main characteristics of the sampling experiments are examined with respect to size and composition by *Gender* and *Age* (proportion and average are obtained on the whole University sample). For each wave, in the second line, the range of such averages among Faculties are also indicated. This gives an idea about how University measures change within the Faculties and confirms that homogeneity during years is higher than among Faculties.

In Tables 2-6 we will show some synthetic measures[1] for the five waves and for all preference data. For all the waves, opinions about *Willingness* constantly manifest the greatest appreciation; on the other hand, the item *Office Hours* everywhere achieves the lowest rates.

In addition, we are introducing a measure called *Positive Evaluation Index* (=PEI), defined as the proportion of respondents which select categories 5 (="satisfied"), 6 (="very satisfied") or 7 (="extremely satisfied"). Thus, it represents the relative frequency of students which are positively satisfied with the item. This measure is strongly related to the average satisfaction (in fact, their correlation is 0.931) but it measures more directly the impact of satisfaction in the whole population since it is not biased

[1] Notice that the average for dichotomous variables should be interpreted as the proportion of the modality coded as 1; for instance, in wave I, 35% of respondents declared regular Frequency of Service and 48% were women.

Table 1. General information and indices about data set.

Year	*Wave*	Sample Size	Proportion of Women	Average of Age (years)	*Global* Satisfaction
2002	I	2179	0.481	22.598	5.718
			[*0.210—0.698*]	[*20.462—24.240*]	[*4.410—6.554*]
2003	II	2535	0.505	22.146	5.621
			[*0.204—0.707*]	[*20.462—26.092*]	[*5.012—6.565*]
2004	III	3183	0.519	22.509	5.668
			[*0.236—0.729*]	[*21.222—25.391*]	[*4.872—6.709*]
2007	IV	3511	0.549	22.081	5.520
			[*0.229—0.818*]	[*19.370—27.634*]	[*4.717—6.555*]
2008	V	4042	0.538	21.953	5.595
			[*0.239—0.786*]	[*19.933—26.360*]	[*4.827—6.481*]

by some possible extreme negative opinions. In this regard, we notice that PEI indexes for *Office Hours* are regularly the lowest whereas for *Willingness* and *Global* items are the highest.

Table 2. Explorative indices for Wave I (2002), $n = 2179$.

Covariate	Mean	Std.Dev
Gender	0.4814	0.4998
Diploma	0.6159	0.4865
Residence	0.7187	0.4497
FreqServ	0.3502	0.4771
Age (17 – 51)	22.5975	3.5770

Item	Mean	Std.Dev	PEI
Information	5.5365	1.4507	0.8284
Willingness	5.9816	1.3222	0.8986
Office Hours	5.2809	1.6054	0.7536
Competence	5.6370	1.4335	0.8375
Global	5.7178	1.3026	0.8674

4. A class of mixture models for ordinal data

There is a large literature on the subject of ordinal data modelling, mainly focussed on Generalized Linear Models framework: Agresti

Table 3. Explorative indices for Wave II (2003), $n = 2535$.

Covariate	Mean	Std.Dev
Gender	0.5049	0.5001
Diploma	0.6544	0.4756
Residence	0.7720	0.4196
FreqServ	0.3243	0.4682
Age (18 – 44)	22.1460	3.1489

Item	Mean	Std.Dev	PEI
Information	5.3791	1.3348	0.7925
Willingness	5.7179	1.2620	0.8631
Office Hours	5.1862	1.4429	0.7314
Competence	5.5132	1.3337	0.8126
Global	5.6205	1.2408	0.8505

Table 4. Explorative indices for Wave III (2004), $n = 3183$.

Covariate	Mean	Std.Dev
Gender	0.5190	0.4997
Diploma	0.6384	0.4805
Residence	0.7496	0.4333
FreqServ	0.3880	0.4874
Age (17 – 51)	22.5099	3.4290

Item	Mean	Std.Dev	PEI
Information	5.4581	1.3076	0.8275
Willingness	5.7776	1.2693	0.8790
Office Hours	5.2023	1.4239	0.7279
Competence	5.5988	1.3160	0.8398
Global	5.6676	1.2113	0.8702

Table 5. Explorative indices for Wave IV (2007), $n = 3511$.

Covariate	Mean	Std.Dev
Gender	0.5486	0.4977
Diploma	0.6668	0.4714
Residence	0.7741	0.4182
FreqServ	0.3164	0.4652
Age (17 – 74)	22.0812	3.9265

Item	Mean	Std.Dev	PEI
Information	5.3404	1.2147	0.8240
Willingness	5.5713	1.2132	0.8607
Office Hours	5.0054	1.2776	0.6921
Competence	5.4899	1.2169	0.8388
Global	5.5195	1.1432	0.8644

Table 6. Explorative indices for Wave V (2008), $n = 4042$.

Covariate	Mean	Std.Dev
Gender	0.5376	0.4986
Diploma	0.6630	0.4727
Residence	0.8016	0.3989
FreqServ	0.3867	0.4871
Age (17 – 58)	21.9532	3.6928

Item	Mean	Std.Dev	PEI
Information	5.4070	1.2112	0.8253
Willingness	5.5777	1.1481	0.8570
Office Hours	5.2427	1.2130	0.7593
Competence	5.5344	1.1567	0.8466
Global	5.5948	1.0981	0.8629

(2002), McCullagh (1980), McCullagh and Nelder (1989). However, a parsimony criterion and the need for a sharp visualization of the impact of covariates support a different paradigm that we present and apply in this paper. Briefly, we interpret the main features of respondents by means of a direct connection to probabilities instead of cumulative probabilities, as it is common in classical modelling approach for ordinal data.

In order to model ordinal data, a general class of probability distributions (defined CUB models) has been proposed by Piccolo (2003), D'Elia and Piccolo (2005), Iannario and Piccolo (2009a), Iannario (2010a,b) and further generalized by Piccolo (2008) and Corduas *et al.* (2010). These structures are characterized by a mixture of two discrete random variables (a shifted Binomial and a Uniform, respectively) which are able to capture *feeling* and *uncertainty* of the respondents with just two parameters.

Briefly, CUB models generate a flexible range of distributions with different location, heterogeneity and shape and have been successfully applied in several fields (as reported in the quoted references). In addition, interpretation and fitting both improve when significant subject's covariates are explicitly included in the model in order to take account of feeling and uncertainty of the respondents.

Formally, given a Likert-type m-point ordered scale, for any $m > 3$, we assume that the ordered responses $r_i,\ i = 1, 2, \ldots, n$ of n respondents are the realizations of a random variable R whose distribution over the support $\{1, 2, \ldots, m\}$ is defined by:

$$P_r\,(R = r;\, \boldsymbol{\theta}) = \pi \binom{m-1}{r-1} (1-\xi)^{r-1} \xi^{m-r} + (1-\pi)\,\frac{1}{m}\,.$$

This family of discrete distributions is characterized by the parameter vector $\boldsymbol{\theta} = (\pi, \xi)'$ and the model is identifiable for $m > 3$, as proved by Iannario (2009b), and the parametric space $\Omega(\pi, \xi)$ is the left open unit square:

$$\Omega(\pi, \xi) = \{(\pi, \xi) :\ 0 < \pi \leq 1\,;\ 0 \leq \xi \leq 1\}\,.$$

For interpreting these parameters, we consider that $\xi \to 0$ ($\xi \to 1$) implies a prevalence of favourable (unfavourable) responses, respectively. Instead, $\pi \to 0$ ($\pi \to 1$) implies an increase (decrease, respectively) in the weight of a completely random assignment of the responses, respectively. As a consequence, it is immediate to interpret $1 - \xi$ as a direct measure of feeling or satisfaction towards the item and $1 - \pi$ as a direct measure of uncertainty in expressing opinions.

In presence of covariates for subjects, by letting $\boldsymbol{\beta} = (\beta_0,\, \beta_1,\, \dots,\, \beta_p)'$ and $\boldsymbol{\gamma} = (\gamma_0,\, \gamma_1,\, \dots,\, \gamma_p)'$, the link functions

$$\pi_i = \frac{1}{1+e^{-\boldsymbol{y}_i\,\boldsymbol{\beta}}}\,; \qquad \xi_i = \frac{1}{1+e^{-\boldsymbol{w}_i\,\boldsymbol{\gamma}}}\,; \qquad\qquad i = 1,2,\dots,n\,,$$

map any linear combinations of real covariates into the unit square, as necessary for a proper definition of a general CUB probability distribution. Notice that some and/or all covariates $\boldsymbol{y}_i = (1, y_{i1}, y_{i2}, \dots, y_{ip})$ and $\boldsymbol{w}_i = (1, w_{i1}, w_{i2}, \dots, w_{iq}$, for $i = 1, 2, \dots, n$ may partially or completely overlap without losing model identifiability.

Then, for inferential purposes, a sample of ratings $\boldsymbol{r} = (r_1, r_2, \dots, r_n)'$ is collected on n respondents together with a set of discrete and/or continuous covariates for each subject. If we denote by $\boldsymbol{y}_i$ and $\boldsymbol{w}_i$ the subjects' covariates related to uncertainty and feeling parameters, respectively, the whole sample data consist of a matrix whose i-th row is specified by $(r_i,\, \boldsymbol{y}_i,\, \boldsymbol{w}_i)'$, for $i = 1, 2, \dots, n$.

After some algebra, the log-likelihood function for the parameter vector $\boldsymbol{\theta} = (\boldsymbol{\beta}', \boldsymbol{\gamma}')'$ of a general CUB model turns out to be:

$$\ell(\boldsymbol{\theta}) = \sum_{i=1}^{n} \log\left[\frac{1}{1+e^{-\boldsymbol{y}_i\boldsymbol{\beta}}}\left\{\binom{m-1}{r_i-1}\frac{e^{-\boldsymbol{w}_i\boldsymbol{\gamma}(r_i-1)}}{\left(1+e^{-\boldsymbol{w}_i\boldsymbol{\gamma}}\right)^{m-1}} - \frac{1}{m}\right\} + \frac{1}{m}\right].$$

An effective EM algorithm for deriving maximum likelihood estimates and performing asymptotic inference has been derived (Piccolo, 2006) and implemented in an effective way in a freely available program (Iannario and Piccolo, 2009b). Further results on fitting measures (Iannario, 2009a) and diagnostic analyses (Di Iorio and Piccolo, 2009) have been also obtained.

A very peculiar feature of CUB models (and their effectiveness as compared with classical ordinal models) is the ability to fit ordinal responses with a parsimonious parametrization since they do not require specification and estimation of cutpoints of a latent variable. Moreover, since there is a one-to-one correspondence between a CUB models and a point in the parametric space $\Omega(\pi, \xi)$, estimated models can be simply represented, compared and discussed with respect to clusters, circumstances and time.

In this way, we are able to visualize in a sharp manner the effect of subjects' covariates in modifying uncertainty and satisfaction as they result from expressed ratings. Since these representations are stylized patterns of parametric models aimed at showing latent components of ordered choices, this approach may also compare experiments with different rating scales insofar as uncertainty and feeling are the relevant constructs to be examined.

In the following sections, we will apply CUB models in order to analyze students' responses and confirm that it is possible to deduce simple interpretations and common features in a modelling framework even if we are faced with a very large data set. In fact, we will study both University in its entirety and each Faculty with respect to the satisfaction expressed by students towards the five items.

5. Models for University

For the whole University, we represent in Figure 1 the estimated CUB models for each wave and item as points in the parametric space. This representation sharply synthesizes students' opinions and we perceive a hooked shape that characterizes all items with respect to years. More precisely, some points deserve consideration:

- Wave 2002 obtains maximum satisfaction with respect to any question, and this undoubtedly is the effect of the novelty in the experience of using an Orientation Service well diffuse throughout University.
- A clear reduction of satisfaction is registered in 2003 and this abrupt change is almost never reversed in 2004. The worsening continues in 2007 (this wave registers a minimum in the frequency of usage of the service) although some minor adjustment may be registered for the final survey in 2008; however, it is generally insufficient to make up previous levels of satisfaction.
- The ranking of items proceed from *Willingness*, *Competence*, *Information* down to *Office Hours*, and this ordering is stable during

the waves. As expected, *Global* satisfaction is consistently intermediate every time.

- Uncertainty in responses is always higher for *Office Hours* and minimum for *Willingness*, confirming a constant positive evaluation for the staff operating in the Service and critical views mainly towards structural aspects. However, this indecision reduces over time monotonically and in a sensible manner for all items, and this circumstance may be caused by a comparative opinion over the years and a more critical expectation towards the service.

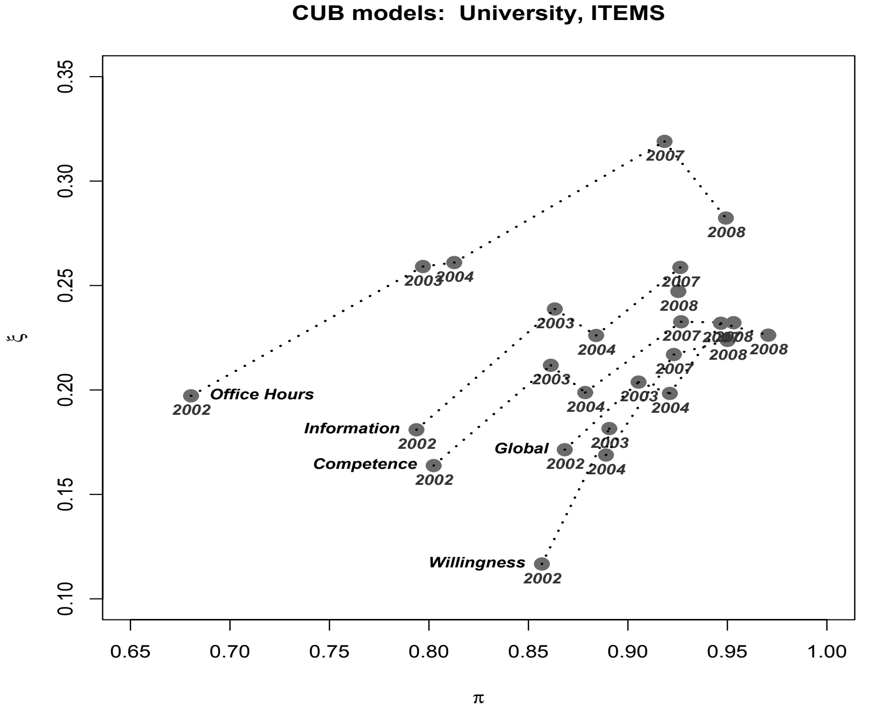

Figure 1. CUB models University with respect to ITEMS/waves.

Behaviour of respondents can be further explored if we relate responses to students' characteristics as *Gender*, *Diploma*, *Frequency of*

Service, *Residence* and *Age*[2]. These analyses should require statistical strategies for the inclusion/exclusion of significant covariates and we opt for a top-down approach by starting with a general CUB model which includes all of them. Since indecision of respondents will be considered in section 8, here we limit ourselves to exploit covariates only for interpreting the students' satisfaction. The small or moderate level of uncertainty which accompanies the expressed ratings supports this view although further refinement could be possible.

For a correct and immediate interpretation of the estimation results, we remember that feeling parameters ξ_i and covariates $\boldsymbol{w}_i$ for the i-th subject are related by:

$$\xi_i = \frac{1}{1 + e^{-\gamma_0 - \gamma_1\, w_{1i} - \gamma_2\, w_{2i} - \cdots - \gamma_q\, w_{qi}}}\,, \quad i = 1, 2, \ldots, n.$$

Ceteris paribus, an increasing value of a single covariate w_k, for $k = 1, 2, \ldots, q$ induces a change of ξ_i in the same direction of the coefficient of γ_k, and a corresponding decrease in the satisfaction (measured by $1 - \xi_i$). For dichotomous variables, an increase of the covariate should be interpreted as moving from the qualitative modality coded as 0 towards the modality coded as 1. Briefly, for positive parameters γ_k, satisfaction increases (decreases) when the covariates decreases (increases), and vice versa for negative γ_k. The scheme in Table 7 summarizes these relationships.

Table 8 synthesizes the results of the estimation of full CUB models for the five items and for each wave. To improve a stylized interpretation, we report the signs of significant parameters and we insert $(\circ)$ for parameters not significant at 5%. Test for the intercept γ_0 are not shown since they are invariably significant.

These models allow several considerations and we focus on few of them:

- Results are generally consistent among items and waves and largely monotonic with regard to the effect of covariates.

[2] It should be remembered that all covariates but *Age* are dichotomous. Moreover, *Age* is firstly transformed by natural logarithms and then scaled by subtracting the average of logged data. This transformation is standard in literature and it is motivated by interpretation and numerical efficacy.

Table 7. Effect of covariates on the subjects' satisfaction.

Parameter γ_k	Covariate w_k	*Satisfaction*
POSITIVE $\Longrightarrow$	Decreases	*Increases*
	Increases	*Decreases*
NEGATIVE $\Longrightarrow$	Increases	*Decreases*
	Decreases	*Increases*

- *Age* is a relevant covariate for the assessment of the satisfaction towards all items and during all waves (an exception seems to be the *Global* response in wave II). The effect is uniformly positive with high significance denoting elder students, and thus with a possible job and/or with breaks during their studies, appreciate the service to a greater extent.
- *Diploma*, as a dummy for classical and scientific studies, is never significant but in wave II. This circumstance has no immediate interpretation but induces a regular positive effect on the expressed satisfaction towards all item and it should deserve an *ad hoc* investigation.
- *Frequency of service* is a proxy of students which regularly attend Orientation Services and ranges in 32-39% within the surveys. Thus, it is important to assess that during the first three waves the effect of frequency is uniformly positive in terms of satisfaction of all items whereas it becomes negative for the last two waves. These results are constant and diffuse and thus they manifest an increased dissatisfaction of students that meet quite often the staff and show that original positive gratitude for receiving information has turned into an increasing critical opinion towards the service, although staff willingness is still appreciated.
- *Residence* is a significant covariate only during wave II (with a negative effect) and V wave (with a positive effect). These relationships manifest for all items and thus deserve accurate consideration; specifically, they show that originally people leaving outside

of the metropolitan area are more satisfied whereas in the last year the reverse is true.

- *Gender*'s effect on satisfaction switches over the years and with respects to items. Specifically, women are positively and uniformly oriented in the first two waves; in wave III significance decreases and in the last two surveys they become more critical, mostly with reference to *Competence* and *Global* items.

The picture that emerges from previous discussion suggests to move towards a comprehensive statistical model for all waves in order to simplify the collection of all data set information in a simple parametric fashion. For achieving this objective we introduce 4 dummy variables which compare each wave to the first one (I), that is:

$$T_{i[k]} = \begin{cases} 1 & \text{if subject } i\text{-th belongs to the } k\text{-th Wave}\,; \\ 0 & \text{otherwise}\,; \end{cases} \qquad k = II, III, IV, V.$$

Following this extension, the comprehensive CUB model for all data set is specified by the following link for the feeling parameter:

$$\xi_{i[k]} \;=\; \frac{1}{1+\exp\{-(\boldsymbol{\gamma}\,\boldsymbol{w}_i + \boldsymbol{\delta}\,\boldsymbol{T}_{i[k]})\}}$$

where we put, for $i = 1, 2, \dots, n_k$ and $k = II, III, IV, V$:

$$\boldsymbol{\delta} = (\delta_{II},\, \delta_{III},\, \delta_{IV},\, \delta_{V})'\,; \qquad (T_{i[II]},\, T_{i[III]},\, T_{i[IV]},\, T_{i[V]})'\,.$$

In Table 9 we present the parameter estimates:

$$\eta_{[I]} = \gamma_0; \qquad \eta_{[k]} = \gamma_0 + \delta_{[k]}\,, \qquad k = II, III, IV, V,$$

and reported values all are significant. Thus, we can an appreciate the effect of all waves in a single scheme.

On these results we add few comments:

Table 8. Significance of estimated CUB *model with covariates for feeling.*

Items	*Gender*	*FreqServ*	*Diploma*	*Residence*	*Age*
Waves →	I II III IV V	I II III IV V	I II III IV V	I II III IV V	I II III IV V
Information	− ∘ ∘ + ∘	− − − + +	∘ − ∘ ∘ ∘	∘ + ∘ ∘ −	− − − − −
Willingness	− − ∘ + ∘	− − − + +	∘ − ∘ ∘ ∘	∘ + ∘ ∘ −	− − − − −
Office Hours	− − ∘ + ∘	− − − + +	∘ ∘ − ∘ ∘	∘ + ∘ ∘ −	− − − − −
Competence	− ∘ + + +	− − − + +	∘ − ∘ ∘ ∘	∘ + ∘ ∘ −	− ∘ − − −
Global	− − ∘ + +	− − − + +	∘ − ∘ ∘ ∘	∘ + ∘ ∘ −	− − ∘ − −

Table 9. Effect of Waves on CUB *models (covariates for feeling).*

Items	$\eta_{[I]}$	$\eta_{[II]}$	$\eta_{[III]}$	$\eta_{[IV]}$	$\eta_{[V]}$	*Gender*	*FreqServ*	*Diploma*	*Age*
Information	−1.397	−1.106	−1.187	−0.894	−0.966	...	−0.108	...	−1.038
Willingness	−1.911	−1.428	−1.512	−1.110	−1.091	...	−0.093	−0.052	−1.118
Office Hours	−1.245	−0.998	−0.985	−0.627	−0.828	...	−0.088	...	−0.844
Competence	−1.537	−1.282	−1.362	−1.006	−1.032	0.075	−0.151	...	−0.937
Global	−1.521	−1.341	−1.383	−1.081	−1.133	0.051	−0.095	...	−0.811

- For all items, waves are progressively reducing their effects with a reduction in trend between II and III waves and between IV and V waves.
- The relative weight of the wave effect is constant denoting a ranking in the items as *Willingness*, *Competence*, *Information*, *Office Hours*, and *Global* generally intermediate among them.
- *Gender* is significant only with regard to *Competence* and *Global* items, and manifests how women are comparatively more critical towards the Service.
- *Frequency of the Service* acts positively to express a satisfaction towards the items, and this is stronger with reference to *Competence*.
- *Diploma* is never significant but for a positive appreciation for *Willingness* expressed by students with classical and scientific background.
- *Age* manifests a positive effect in a regular manner with respects to all items. Older people appreciate mostly *Willingness* and *Information*.

If we replicate for all Faculties the analysis that produced Figure 1, we get a similar representation that we do not show for brevity. However, this complex picture enhances many features that would be more interesting for comparative interpretation if we could label Faculties and relate expressed responses to difficulties in studies.

6. The behaviour of students who changed Faculty

Students who moved among Faculties in course of studies are a subset of students who manifest implicit or explicit difficulties with University career, and they may be considered as “natural” users of Orientation Services. We will study their characteristics in terms of the expressed satisfaction and will begin by showing in Table 10, for each Faculty and wave, the proportion of respondents who changed the Faculty of their first enrollment.

It seems evident that such values are heterogeneous among Faculties and waves, although some increase over the years may be registered (for

Table 10. Proportion of respondents who changed Faculties.

Faculty	Wave I	Wave II	Wave III	Wave IV	Wave V
1	0.060	0.034	0.029	0.068	0.238
2	0.029	0.027	0.023	0.017	0.034
3	0.114	0.070	0.052	0.033	0.031
4	0.030	0.021	0.028	0.058	0.191
5	0.107	0.036	0.049	0.114	0.092
6	0.087	0.043	0.072	0.026	0.084
7	0.113	0.143	0.115	0.143	0.212
8	0.243	0.178	0.209	0.328	0.201
9	0.400	0.217	0.160	0.065	0.168
10	0.077	0.020	0.016	0.158	0.031
11	0.170	0.049	0.076	0.137	0.183
12	0.077	0.104	0.098	0.099	0.219
13	0.096	0.062	0.072	0.161	0.134

instance, in waves IV and V), mainly due to an increase of the awareness and usefulness of Orientation Services for giving support to students who moved among Faculties. Such large variability in the structure of respondents is one of the reason we exclude it from the previous general analysis, although in some circumstance it should be considered as a useful indicator for predicting students' satisfaction.

Then, we estimated CUB models by considering *Change-of-Faculty* as a sensible subjects' covariate for explaining feeling towards the five items considered in this paper. Indeed, we just show in Table 11 the sign of the estimates only when this covariate turned out to be significant for waves and items as listed.

For immediate interpretation we exploit the scheme proposed in Table 7; thus, last two waves show a strong, uniform and negative effect of respondents who changed Faculties on the expressed satisfaction. In other words, in more recent years users of Orientation Services who experienced a change of Faculty expressed a more critical judgement towards Orientation Services. Estimated CUB models, here not reported, disclose that this moderate dissatisfaction is greater with respect to *Information* and this fact might explain a relatively lower rating.

Table 11. Effect of the proportion of respondents who changed Faculties.

Items	Wave I	Wave II	Wave III	Wave IV	Wave V
Information	○	○	+	+	+
Willingness	○	○	○	+	+
Office Hours	○	○	○	+	+
Competence	○	○	+	+	+
Global	○	○	+	+	+

7. The effect of Age on the expressed satisfaction

Age is a relevant covariate for explaining our data set as confirmed by results obtained in section 5. This variable changes in a sensible manner among Faculties and during waves, as confirmed by Table 12.

Table 12. Average of covariate Age with respect to Faculties and waves.

$Faculty/Waves$ $\rightarrow$	I	II	III	IV	V
1	21.840	23.483	23.059	24.149	22.543
2	23.114	26.092	25.391	21.636	24.837
3	22.000	22.189	21.971	23.115	21.456
4	22.414	20.462	21.222	22.072	21.220
5	22.703	22.039	23.020	22.278	22.452
6	23.140	21.671	22.846	19.370	19.933
7	22.517	21.941	21.860	22.140	22.960
8	23.000	22.364	21.849	21.060	20.651
9	24.240	23.000	23.309	24.234	21.811
10	20.462	20.571	21.951	22.267	20.805
11	22.094	21.188	22.245	21.521	21.000
12	22.654	21.887	21.378	27.634	26.360
13	22.072	22.075	21.860	23.489	22.324
$University$	22.598	22.145	22.509	22.081	21.953

Previous analysis has shown that satisfaction is regularly higher as far as age increases and thus the covariate *Age* is significant almost everywhere with respect to waves and items, for all Faculties. To motivate this assertion, and also to discriminate among Faculties, we present the percentage of increase in estimated log-likelihood[3] for CUB models without covariates and with addition of the *Age* covariate (deviations from the average of each wave, after logging). Specifically, Table 13 reports the following relative measure:

$$100 \times \left| \frac{\ell_0 - \ell_{Age}}{\ell_0} \right| ,$$

for all Faculties and the five items, during all the waves. Thus, discrimination of the effect is with respect to Faculties and items, assuming a relative homogeneity during the years.

Table 13. Effect of covariate Age on relative variation of log-likelihood.

Faculty	*Information*	*Willingness*	*Office Hours*	*Competence*	*Global*
1	0.121	0.258	0.102	0.026	0.036
2	0.438	0.903	0.082	1.609	2.789
3	0.171	0.116	0.001	0.111	0.067
4	0.107	0.021	0.000	0.042	0.101
5	0.082	0.032	0.001	0.013	0.059
6	0.154	0.225	0.363	0.092	0.130
7	0.045	0.013	0.039	0.005	0.056
8	0.273	0.940	0.698	0.531	0.455
9	2.192	1.373	0.797	1.293	1.356
10	0.562	0.089	0.481	0.078	0.296
11	0.258	0.172	0.197	0.083	0.059
12	5.157	4.697	2.090	4.928	3.801
13	1.094	0.929	0.121	0.592	0.594

Faculties 2, 9 and 12 register an high impact of *Age* on the expressed satisfaction and this circumstance is also supported by an higher average of the age of the respondents selected in these Faculties.

Correlations among the *Global* satisfaction effect and the average age in the Faculty change during waves and assume values 0.329, 0.463,

[3] This is a descriptive and immediate measure for quantifying the importance of *Age*. from a statistical point of view, this measure is related to a more formal likelihood ratio test for checking the relevance of *Age*. In our case-study, this test turned out to be largely significant.

0.257, 0.568, 0.817, respectively. This confirms that in recent years the Orientation Service of the whole University enhanced its role in favour of students with age elder than the average.

8. Assessing uncertainty of customer satisfaction

Previous studies are based on a constant uncertainty parameter through different clusters, waves and Faculties. In fact, it is interesting to see how uncertainty changes with the characteristics of data set under modelling. Generally speaking, satisfaction has been expressed with a low uncertainty under any circumstance and this is the direct consequence of some facts related to this peculiar survey that we briefly list:

- Interviews are collected within or in the surroundings of the offices where service is operating. Thus, respondents are concentrated on questions and have enough time to give meditated responses.
- Questionnaire is very short and requires few minutes to answer all items: this reduces the risk of confusion, indecision, joking or fake answers. Moreover, for filling the responses related to subjects' covariates, the choice is oversimplified and is always limited to a definite list of modalities.
- Items concern several aspects of the relationship among Service and students; however, they are simply related to only two principal components, which are personal effects and structural effects. This way, the perception of agreement or disagreement is strongly simplified and the expressed satisfaction resulted in a well definite and consistent assessment.

Given these facts, we explore how uncertainty varies among Faculties, waves and subjects' characteristics. We estimate several CUB models without covariates and then CUB models with covariates: in this case, we have chosen covariates that are able to explain the uncertainty parameter of the model in a significant measure.

Table 14 lists the uncertainty parameter $\hat{\pi}$ as estimated by CUB models for given waves and items. For any correct consideration, notice that it is the quantity $1 - \pi$ which is directly related to uncertainty.

The general pattern of this table (as already anticipated by Figure 1) confirms that uncertainty is a component whose weight is systematically reducing in the last waves, and this statement is the consequence of an increasing diffusion of evaluation techniques in the University arena. In fact, during their University life, most of respondents experienced more than a questionnaire requesting rated judgements on teaching, structures, services, and so on.

As one could expect, such results are less definite and uniform since uncertainty in this data set is generally moderate or quite absent; as a consequence, it will depends in a weak measure by some covariates. Table 15 summarizes all estimated CUB models with uncertainty explained by relevant covariates.

In this context, the pattern is not so definite, except for the *Frequency of Service* variable which constantly exerts a negative influence on the uncertainty. More precisely, users which regularly or often attend the service manifest more resolute responses, and so with a lower uncertainty. All other covariates, when significant, contributes to lower uncertainty as *Gender* for instance (women are less uncertain).

Table 14. Significance of covariates for uncertainty.

Items	*Gender*	*FreqServ*	*Diploma*	*Residence*	*ChangeFac*	*Age*
Waves →	I II III IV V	I II III IV V	I II III IV V	I II III IV V	I II III IV V	I II III IV V
Information	+ ∘ ∘ + ∘	+ + + + +	∘ + + ∘ +	∘ ∘ + ∘ ∘	∘ ∘ + + +	+ + ∘ ∘ ∘
Willingness	+ + ∘ + ∘	+ + + + +	+ + ∘ ∘ ∘	∘ ∘ + ∘ ∘	∘ ∘ + + +	+ + + ∘ ∘
Office Hours	+ + ∘ ∘ ∘	+ + + ∘ +	∘ ∘ ∘ ∘ +	∘ ∘ ∘ ∘ +	∘ ∘ ∘ ∘ ∘	+ ∘ + ∘ ∘
Competence	+ ∘ ∘ + +	+ + + + +	∘ ∘ + + +	∘ ∘ ∘ ∘ +	∘ ∘ + ∘ ∘	+ ∘ + ∘ ∘
Global	+ ∘ ∘ + +	+ + + + +	+ ∘ + ∘ ∘	∘ ∘ ∘ ∘ +	∘ ∘ + + ∘	∘ ∘ ∘ ∘ ∘

Table 15. Uncertainty estimates ($\hat{\pi}$) with respect to items and Faculties for waves.

2002	1	2	3	4	5	6	7	8	9	10	11	12	13
Inform	.734	.841	.797	.941	.984	.550	.948	.903	.833	.773	.789	1.000	.757
Willing	.924	.880	.933	.924	.990	.624	.958	.923	.779	.747	.789	1.000	.557
OffHour	.798	.677	.853	.904	.970	.512	.398	.855	.821	.589	.649	.924	.776
Compet	.802	.856	.770	.935	.987	.539	.946	.981	.874	.956	.772	.915	.796
Global	.843	.882	.938	.939	.983	.662	.976	.999	.956	1.000	.858	1.000	.678
2003	1	2	3	4	5	6	7	8	9	10	11	12	13
Inform	.931	.788	.815	.989	.978	.942	.871	.986	1.000	.946	.895	.737	.880
Willing	.930	.910	.829	.989	.986	.871	.893	.945	1.000	.910	.932	.881	.854
OffHour	.894	.697	.796	1.000	.948	.830	.891	.923	.802	.871	.741	.679	.681
Compet	.865	.907	.816	.999	.995	.986	.823	.904	1.000	1.000	.909	.713	.712
Global	.961	.915	.874	.993	1.000	.972	.884	.928	1.000	1.000	.933	.708	.901
2004	1	2	3	4	5	6	7	8	9	10	11	12	13
Inform	1.000	.960	.819	1.000	.900	.781	.932	.862	1.000	.978	.967	.893	.963
Willing	.904	.936	.817	1.000	.916	0.795	.909	.824	1.000	.942	.965	.832	.969
OffHour	.903	.726	.822	1.000	.846	0.756	.903	.875	.604	.873	.828	.881	.866
Compet	.900	.931	.819	1.000	.946	0.794	.921	.881	1.000	.964	.928	.756	.932
Global	.970	.949	.870	1.000	.960	0.855	.942	.916	1.000	.966	.977	.870	.967
2007	1	2	3	4	5	6	7	8	9	10	11	12	13
Inform	.979	.861	.932	1.000	.996	.996	.829	.873	.980	.922	.952	1.000	.975
Willing	.911	.873	.943	.918	.991	1.000	.835	.849	.912	.917	.879	1.000	.965
OffHour	1.000	.802	.917	1.000	.985	.989	.915	.918	1.000	.893	.932	1.000	.930
Compet	.954	.832	.947	.948	.994	1.000	.797	.901	.956	.942	.927	1.000	.986
Global	.985	.853	.977	1.000	0.990	1.000	.884	.828	.987	.949	.970	1.000	1.000
2008	1	2	3	4	5	6	7	8	9	10	11	12	13
Inform	0.871	0.838	0.990	0.966	0.975	0.942	0.917	0.912	0.989	0.915	0.956	0.958	0.922
Willing	0.992	0.852	0.995	0.988	0.957	0.946	0.957	0.939	1.000	0.974	0.943	0.984	0.945
OffHour	0.910	0.703	0.996	0.960	0.956	0.948	0.991	0.969	1.000	0.994	0.887	0.973	0.946
Compet	0.935	0.774	0.996	1.000	0.961	0.973	0.926	0.953	1.000	1.000	0.960	0.975	0.952
Global	1.000	0.859	0.992	1.000	0.971	0.984	0.985	0.973	1.000	1.000	1.000	0.984	0.940

9. Concluding remarks

In this paper we discussed CUB model approaches to measure and compare satisfaction expressed by students towards University Orientation Service during repeated surveys in the years $2002 - 2008$. The analysis allowed to detect some trends in the respondents' behaviour and to relate observed patterns to the subjects' characteristics.

The results show that *Age* is one of the most relevant covariate for explaining and predicting preferences since it turns out that older respondents are by far the most satisfied, and this acts for all Faculties and waves. This uniform behaviour is partly mitigated by more critical considerations expressed by students who changed the Faculty of their first enrollment, since generally their age is higher that the average.

The study of uncertainty in the responses is a more difficult task since (with the exception of *Office Hours*) it is generally quite low for each item and Faculty. This is the joint effect of the peculiar way survey has been conducted by (accuracy in collection of data, privacy offered to respondents) and the simplified structure of the questionnaire (few and easy wording of the questions).

Finally, such work confirms the usefulness of this class of mixture models as a synthetic and effective way to represent large mass of ordinal data in a convenient and uniform framework. Thus, latent components of satisfaction and uncertainty are enhanced, monitored and tested with respect to time, circumstances and subjects' covariates.

Acknowledgements: This work has been supported by a MIUR grant (code 2008WKHJPKPRIN2008) for the project: "Modelli per variabili latenti basati su dati ordinali: metodi statistici ed evidenze empiriche" within the Research Unit of University of Naples Federico II (`CUP number E61J10000020001`).

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