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MULTILEVEL MODELS IN EDUCATIONAL PROCESS PERFORMANCE EVALUATION

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Abstract: The scope of the paper is to present how multilevel models can be used in educational process performance evaluation. In the first part educational process is defined, with a particular attention to educational process performance, efficiency effectiveness and hierarchical structure of the educational process. The second part of the paper is dedicated to multilevel models, their characteristics and application. The last part of the paper shows how a basic two-level regression model can be set up and used in students' satisfaction evaluation.
Key words: educational process**,** hierarchical structured data, educational process performance, educational process efficiency and effectiveness, multilevel models.

Sažetak: VIŠESTUPANJSKI MODELI U PROCJENI PERFORMANSE PROCESA VISOKE NAOBRAZBE. Svrha rada bila je prezentirati način korištenja višestupanjskih modela u procjenjivanju performanse procesa visokog obrazovanja. U prvom dijelu rada definiran je obrazovni proces, a posebna pažnja posvećena je definiranju efikasnosti i efektivnosti obrazovnog procesa, te objašnjavanju njegove hijerarhijske strukture. Drugi dio rada posvećen je prikazivanju hijerarhijskih linearnih modela, njihovim osobinama te mogućnostima primjene. Osnovni višestupanjski regresijski linearni model te njegova primjena u procjeni performanse obrazovnog procesa prikazani su u posljednjem dijelu rada.
Ključne riječi: obrazovni proces, hijerarhijski strukturirani podaci, performansa obrazovnog procesa, efikasnost i efektivnost obrazovnog procesa, višestupanjski modeli.

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INTRODUCTION

Evaluation of educational processes, as an instrument of achievements analysis, assumes great importance in recent times. Educational process performance evaluation needs special techniques and models that take into account the particular nature and typology of the same educational processes.

The purpose of these models is to give an accurate analysis of the present situation, especially in the light of radical changes required from the Bologna Process, accent the features of single universities and faculties and evidence eventual nonconformities or problems present in an educational process.

Educational process can be burdened by different problems that reduce its performance. Some of the critical points of an educational process are: abandoning of the studies, time needed to graduate, lacks in relationships between universities and labor market, bad study dynamics, low capability of the process to suit the needs, wishes and expectations of students as users. Analyzing, eliminating or reducing these problems need the definition of a set of indicators for educational process monitoring and evaluating as well as implementation of adequate quantitative tools.

The purpose of this paper is to give an overview of a particular econometric instrument, the multilevel models, which can be used in educational process performance evaluation.

Multilevel models are known by several names: hierarchical models, generalized linear mixed models, nested models and split-plot diagrams. They are statistical models with model parameters arranged in a particular hierarchical structure. They are used when some of the investigated variables varies at more than one level.

Multilevel models have been and still are broadly use in education process evaluation, to estimate separately the variance between students within the same faculty or study program, and the variance between faculties. Many authors have researched and investigated the multilevel models problematic, their characteristics and construction, parameters estimation, as well as numerous fields of application. A list of some of these authors is given at the end of this paper.

The scope of this paper was to present how multilevel models can be used in high educational process performance evaluation. This paper can be, therefore considered as an author's attempt to investigate a basic two-level model and its usage in educational process effectiveness evaluation. For this purpose the author of this paper used as reference some of the most eminent names in this research field.

1. EDUCATIONAL PROCESS PERFORMANCE EVALUATION

Educational process performance evaluation is nowadays the topic of many discussions, papers and researches. It requires the application of particular and specific econometrical and statistical methodologies that take into account the particular nature of the same educational process. Educational process evaluation is an important source of information. In fact it allows having information about:

- resources (financial, structural, teachers and administrative staff) assign to didactic activities
- didactic activity (organization, teaching coordination, assign credits)
- additional, support services (tutorial, libraries)
- student's careers (abandoning, credits acquisition, time needed to get the diploma, post-graduate formation)
- teachers activities
- study programs or courses characteristics
- student's employment and their careers.

These information can be used as starting points in educational process improvement and achieving higher level of educational process standards.

1.1. Educational process efficiency and effectiveness

Educational process performance is usually measured through its efficiency and effectiveness (Lockheed and Hanushek, 1994) and can be limited to the education system (internal) or can also include the educational environment (external) by comparing the effects of resources implementation in education or other sectors.

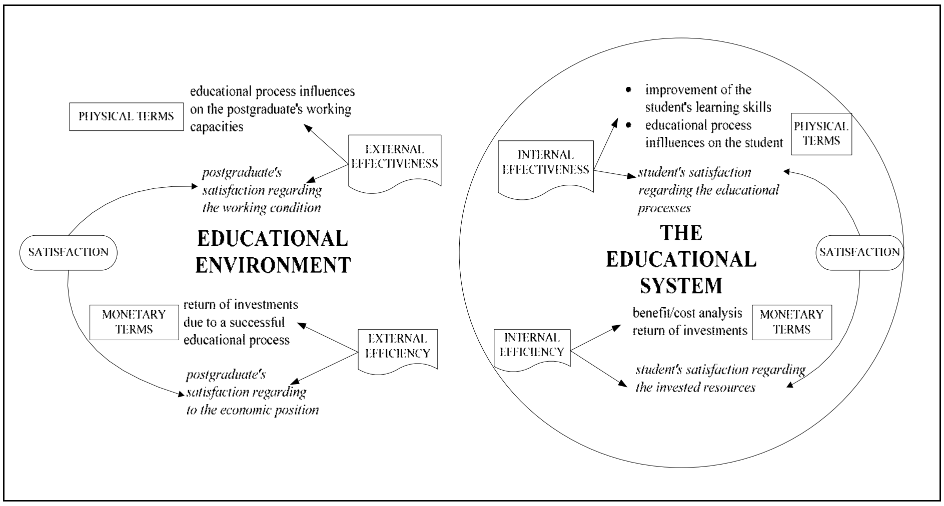
Each, efficacy and efficiency measures should arise from a detailed educational standards analysis. It is obvious that the evaluation process presents different connotation according to the evaluation goals, but the final scope is always educational process analysis, control and improvement of its performance.

Generally, educational process efficiency can be defined as a relation between the results in terms of outputs (delivered educational service) and the inputs in terms of production factors utilized for delivering the educational service. The main problem of educational process efficiency evaluation is the definition and the measurement of input and output components.

Educational process effectiveness can be defined as the process ability to achieve defined goals and wanted effects (the results – goals ratio). It can be identified in the customer's satisfaction with delivered service. Educational process effectiveness evaluation differs regarding to the various stakeholders (the students, the teachers, the suppliers, the partners, the University, the labor market and so on).

This contribution is a starting point for educational process evaluation. Figure 1 presents a concept of the education process evaluation (Lockheed and Hanushek 1994).

Figure 1: Educational evaluation optics



Source: Adapted from Lockheed, M. E., Hanushek, E. (1994), Concepts of Educational Efficiency and Effectiveness, HRO Working Paper, n. 24, March and La valutazione dell'attivita' universitaria: strutture e ricerca, Accademia Nazionale dei Lincei, 2005.

This paper deals with the educational process effectiveness evaluation from the students' point of view. Students, as users of educational process, have well designed expectations, needs and whishes about the educational service they expect to receive. The more educational process meets students' expectations the more they are satisfied, the process effectiveness is greater and the educational process is more capable.

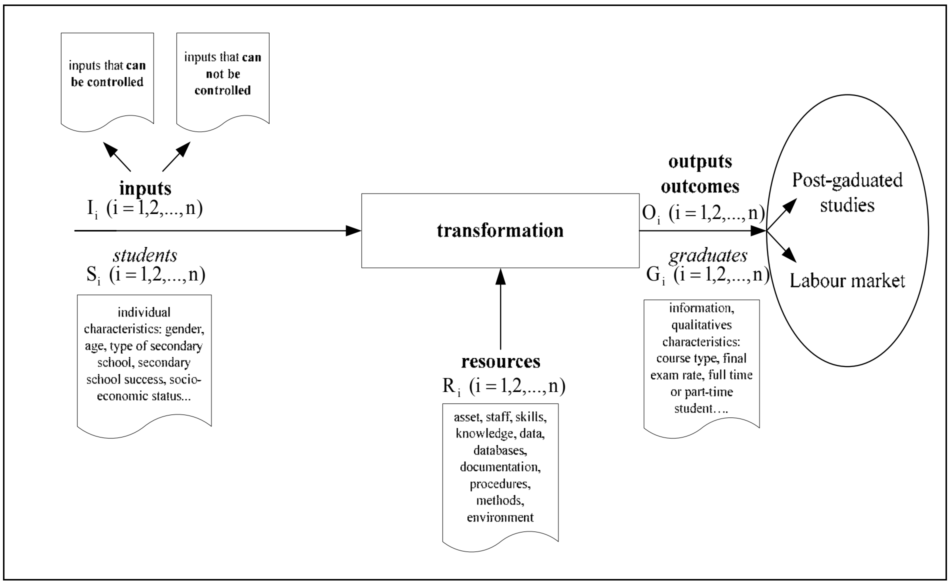
Therefore, educational process capability study is about researching the process ability of being stable and capable to produce results that meet students' expectations and about improving its effectiveness.

Competitiveness and success request effectiveness and efficacy. Educational service conformity becomes a function of high educational institutions capability to optimally (effectively and efficiently) satisfy stake-holders wishes, needs and requests.

1.2. Educational process as a hierarchical phenomenon

An educational process (Figure 2) can be defined as a flow of organized activities, planned and assigned to reach a designed result with the employ of given inputs, resources and customer's needs.

Figure 2: The Educational Process



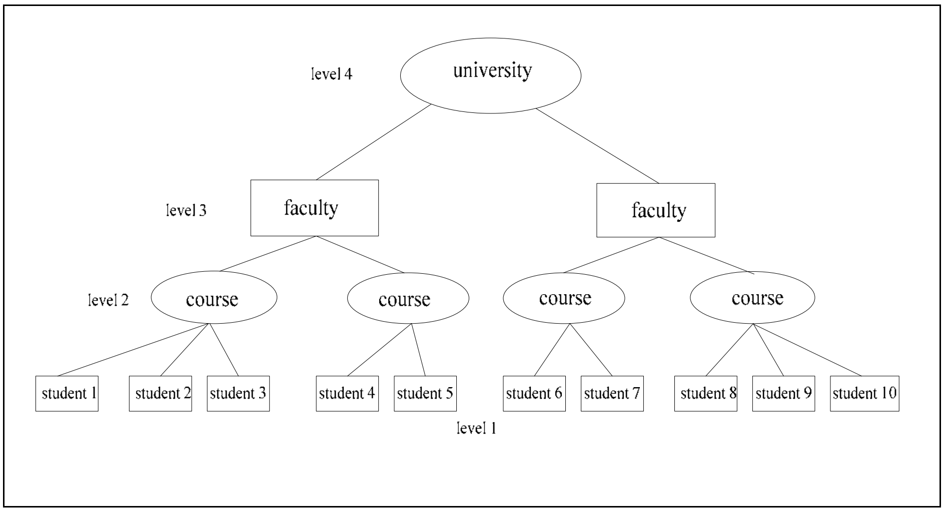
Source: Adapted from Bini, M., Bertaccini, B. (2005), Modelli per la valutazione degli sbocchi occupazionali, Scuola SIS – Metodi statistici per la valutazione e il monitoraggio della formazione universitaria", Firenze, 10-14 ottobre, p. 6.

The most relevant input are the future students S_i coming from different secondary schools, each with its own and particular individual characteristics (gender, age, diploma, secondary school success, entering exam ratings, socio-economic background, etc.). Educational process transformation is the activity of transforming inputs in outputs, using the resources R_i: teaching staff, administrative staff, classrooms, libraries, laboratories, teaching methods, etc.). Graduates G_i represent educational process outputs.

Each of them presents specific individual characteristics achieved during transformation activity. We cannot refer to students as to a real output, because education belongs to the experience good services (Bini, 1999) where the qualitative characteristics cannot be evaluated ex-ante. In these types of services the consumer can not evaluate the service characteristics before the same service is delivered, but after have benefit from the service and the quality of service is in relationship with the results, often called outcome.

An educational process as a particular complex social phenomenon is characterized by hierarchical or clustered structure. We refer to a hierarchy as consisting of units grouped in different levels. In an educational process students are clustered within classes; the classes are grouped within courses or study programs that are clustered within faculties, faculties are grouped within universities (Figure 3).

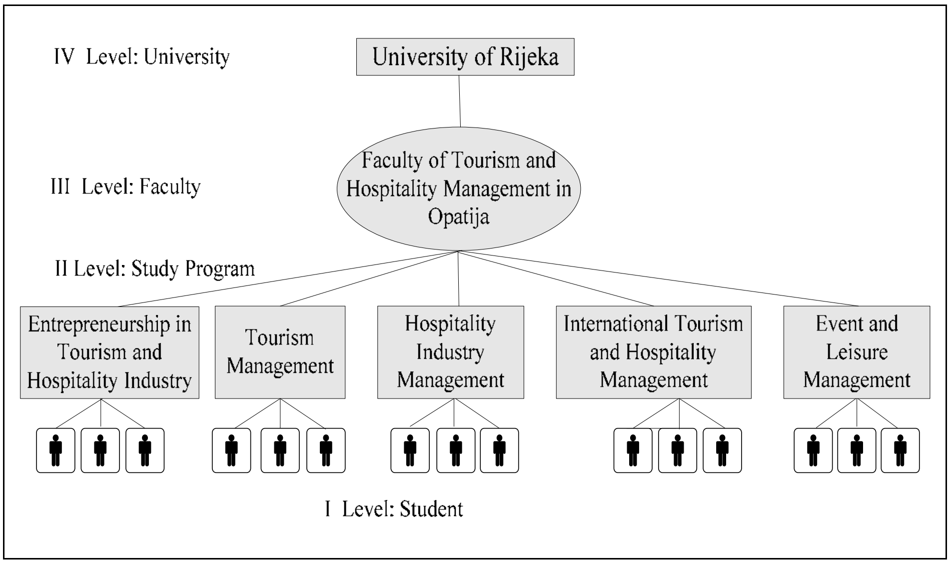
Figure 3: Educational system hierarchical structure



Source: elaborated by author

To better understand the hierarchical nature of an educational process, an example is given in Figure 4.

Figure 4: Hierarchical structure of the Faculty of Tourism and Hospitality Management



Source: elaborated by author

Figure 4 analyses the faculty of Tourism and Hospitality Management in Opatija. As shown in the figure above, there are four levels of data grouping. Students (grouped in different classes, level I) are clustered in several study programs (level II), which are nested in the Faculty (level III) as a component of the University in Rijeka (level IV).

The general concept is that students are influenced by a specific study program they are enrolled to, and that the characteristics of those study programs in turn are influenced by the students who make up that study program. The students and the study programs are conceptualized as a hierarchical system, with students and study programs defined at separate levels of this hierarchical system. Such system can be analyzed at different hierarchical levels and may have variables that describe the students and variables that describe the study program. It has to be pointed out that the individual observations are not completely independent. In fact, is common, that individuals within a group are more similar in comparison with individuals from other groups.

Students in the same study program tend to have more common characteristics and be similar to each other than students from other study programs. As a result, the average correlation (expressed in the so-called intra class correlation (Hox, 1995)) between variables measured in students from the same study program will be higher than the average correlation between variables measured on students from different study programs.

Consequently, the quantitative analysis of an educational process needs special techniques that take into account this particular hierarchical nature of the phenomenon.

2. MULTILEVEL MODELS AND EDUCATIONAL PROCESS EVALUATION

Multilevel models are a more advanced form of *simple and multiple linear regression* models. The classical regression models, adopted for investigate the relationships between one ore more independent variables and a dependent one, are based on the hypothesis of non-correlation between data.

This hypothesis is violated in the case of clustered data. In fact, is common, that individuals within a group are more similar in comparison with individuals from other groups. In this case, the analysis of the individuals as non-correlated leads to distortions: underestimation of standard error of the model or the attribution of non-existing statistical effects between variables. In order to prevent and eliminate these errors, numerous econometrics methods have been developed and among others the multi-level regression models, which take into account the hierarchical structure of the observed data.

2.1. Multilevel models – concept and features

Multilevel models deal with the analysis of data where observations are nested within groups. Social, behavioral and even economic data often have a hierarchical structure.

Since hierarchical data are extremely common in phenomenon studied by social scientists, multi-level modeling has been increasingly popular since the last decade of the last century. Multilevel models are developed for analyzing phenomena that present two special characteristics (Bini, 1999):

1. Observations can concern single statistical units or groups of these units. The phenomena present therefore, a hierarchical structure. If two wholes A and B are given, we define hierarchical a partition in groups of a whole of statistical units, if one and only one of the following possibilities takes place: (a) $A \cap B$; (b) $A \subset B$; (c) $B \subset A$.
2. The phenomena are influenced by a certain number of measurable factors and a certain number of non measurable or non measured factors.

A multilevel model is one with a single dependent variable located at the base level. There may be additional independent variables at the base level also, as in simple or multiple regression. In addition there will be at least one higher level with at least one explanatory variable each. In the regression model, base level data would be analyzed for all groups pooled together. However, in a multilevel model one is performing the regression for the base-level dependent on the base-level independents separately for each group. This results in different regression coefficients and different intercepts. The variation in these coefficients and intercepts is why multilevel models are called "random coefficient" models, though this is a bit of a misnomer since multilevel algorithms use higher level independent variables to predict at least some of the variation in base-level coefficients and intercepts.

In a multilevel model the number of parameters may be very large compared to a regression model. Multilevel models involves not only slopes, intercepts, and variances at the base level, but also slopes for higher level independent variables, slopes for cross-level interactions, covariances among all higher level slopes, covariances of the higher level intercept with all slopes, and higher level error variances for the base-level slopes.

Multilevel modles allows variance in outcome *variables* to be analysed at multiple hierarchical levels, whereas in simple linear and multiple linear regression all effects are modeled to occur at a single level. Thus, hierarchical linear modeling is appropriate for use with nested data. Hierarchical data are normally obtained by multistage sampling. For instance, one might sample faculties within universities, then sample students within sampled faculties.

The peculiarity of these models is the presence of more than one disturbance (one for each level of data grouping).

As said before, multilevel analysis is based on the specification of a regression model that takes into account the existence of groups of statistical units; that implies that the multilevel model, in comparison with a classical regression model, allows also to (Bini, 1999):

- estimate the variation of the hierarchical levels;
- insert explicative variables concerning groups which are indexed at group level and consequently estimate the effects that the group have on the response variable;
- produce more correct estimation parameters standard errors (Longford, 1993);
- study a phenomenon using a regression function independently from the complexity of the hierarchy (Longford, 1993).

Before multilevel modeling became well developed as a research tool, the problems of ignoring hierarchical structures were reasonably well understood, but they were difficult to solve because powerful general purpose tools were unavailable.
An educational process, as a complex socio-economic phenomenon, presents some peculiarities, both in its typology and nature; multilevel models are therefore, very powerful instruments to be used in its performance evaluation.

2.2. The basic two-level regression model

In order to give an example of a multilevel model we suppose to investigate students' satisfaction with the chosen study program, therefore we have to set up a basic two-level regression model.

The assumption is that students in the same study program are likely to be more similar than students in different study programs. Due to this, the variations in outcome, expressed as students' satisfaction, may be due to differences between study programs, and to individual students' differences within a study program. Thus, variance component models, where disturbance may have both a group and an individual component, can be of help in analyzing data of this nature. Within these models, individual components are independent, but while group components are independent within groups, they are perfectly correlated within the groups (Hox, 1995).

Multilevel models allow characteristics of different study programs to be included in models of individual students' behavior.

Educational process capability to meet students' expectations, wishes and needs can be measured by using students' ratings that are widely recognized measures for educational process evaluating and analyzing. Moreover, if one wishes to investigate the student's satisfaction as a dependent variable, it should be recognized that the satisfaction of a student, expressed by the ratings, depends on (Rampichini, Grilli, Petrucci, 2004):

- characteristics of the student (background, secondary school success, expectations, etc.);
- characteristics of the study program (subject-matter, organization, professor, reading);
- characteristics of the course of the study or of the school or department (halls, laboratories, student guidance, etc.);
- characteristics of the University.

We assume that students' satisfaction depend on their average secondary school grade and on the number of subjects of the specific study program[2]. We have, on the student level (first level), the dependent variable *students' satisfaction (Y)*, and the explanatory variable *average secondary school grade (X)*, and on the study program level (second level) the explanatory variable *number of subjects (Z)*.

The simple regression equation for predicting the response variable *Y* by the explanatory variable *X* is (Hox, 1995):

$$Y_{ij} = \beta_{0j} + \beta_{ij} X_{ij} + e_{ij} \tag{1}$$

where:

- Y_{ij}: response variable (student satisfaction)
- X_{ij}: explanatory variable on first level(average secondary school grade)
- β_{0j} is the intercept (model constant)
- β_{ij} is the regression coefficient (regression slope)
- e_{ij} is the residual error term with $e_{ij} \sim N(0, \sigma^2)$
- *j* is for the study program level
- *i* is for the student level

According to Hox, by using the above equation, we can predict students' satisfaction as a dependent variable using average secondary school grade as an explanatory variable in each study program. The difference with the usual regression model is that we assume that each study program is characterized by different intercept coefficient β_{0j} and a different slope coefficient β_{ij} (Hox, 1995).

Consequently we can assume that each study program is therefore characterized by a different value for the intercept and for the slope coefficient for the students' variable average secondary school grade. The differences in the values for the slope coefficient for the explanatory variable X can be interpreted to mean that the relationship between the students' average secondary school success and their satisfaction with the study program is not the same in all study programs.

[2] In order to give an example of using multilevel modeling in educational process evaluation the author of this paper refers, for this part of the paper, to Hox, J.J., Applied Multilevel Analysis, TT-Publikaties, Amsterdam, 1995.

We have now to predict the variation of the regression coefficients β_j by introducing explanatory variables at the study program level (Hox, 1995):

$$\beta_{0j} = \gamma_{00} + \gamma_{01} Z_j + u_{0j} \tag{2}$$

and

$$\beta_{1j} = \gamma_{10} + \gamma_{11} Z_j + u_{1j} \tag{3}$$

Referring to Hox equation (2) assumed that students' satisfaction level of a study program (the intercept β_{0j}) can be predicted by the number of subjects (Z).

Equation (2) and (3) can be substituted into equation (1) as follows (Hox, 1995):

$$Y_{ij} = \gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} Z_j X_{ij} + u_{1j} X_{ij} + u_{0j} + e_{ij} \tag{4}$$

The feature of (4) which distinguishes it from standard linear models of regression or analysis of variance is the presence of more than one residual term and it implies that special procedures are required to obtain satisfactory parameter estimates[3]. In (4) we have expressed the response variable Y_{ij} – student's satisfaction (students' ratings) as the sum of a fixed part ($\gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} Z_j X_{ij}$) and a random part ($u_{1j} X_{ij} + u_{0j} + e_{ij}$). The structure of the random part of the model is the key factor. In the fixed part the variables can be measured at both levels, so we can measure characteristic of students as well as study program features.

The term *ZjXij* is the is an interaction term that appears in the model as a consequence of modeling the varying regression slope β_{1j} of student level variable *Xij* with the study program level variable *Zj*[4].

Model specification depends, of course, on the complexity grade of the phenomenon we want to analyse and on its characteristics.

After all said, it has to be pointed out that the presented model was an author's attempt to illustrate how a two-level model can be used in educational process effectiveness evaluation.

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[3] For more details on parameter estimation and the variance components model see Goldstein, H.: Multilevel Statistical Models, 3rd Edition, Hodder Arnold, 2003, London.

[4] For mode details see Hox, J.J., Applied Multilevel Analysis, TT-Publikaties, Amsterdam, 1995.

CONCLUSIONS

The purpose of this paper was to introduce multilevel models. Multilevel analysis is a very complex field. Multilevel models are a more advanced form *of simple linear regression* and *multiple linear regression* used for hierarchical structured phenomenon analyzing. Social, behavioral and even economic data often have a hierarchical structure. A good example of hierarchical phenomenon is educational process.

These models are much more flexible in the fact that they are capable of handling unbalanced data, the analysis of variance-covariance components and the analysis of both continuous and discrete response variables. As the characteristics of individual groups are incorporated into the multilevel model, the hierarchical structure of the data is taken into account and correct estimates of standard errors are obtained. The exploration of variation between groups, which may be of interest in its own right, is facilitated. Valid tests and confidence intervals can also be constructed and stratification variables used in the sample design can be incorporated into the model.

Most analyses of social sciences data entail the analysis of data with built-in hierarchies, usually obtained as a sequence of complex sampling methods. Thus, the scope for application of multilevel models is very wide. The formulation of such models and estimation procedures may be seen as an effort to develop a new family of analytical tools that correspond to the classical experimental designs.

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