Module 8: Multilevel Modelling in Practice: Research Questions, Data Preparation and Analysis

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Pre-requisites

Modules 1-5

Contents

8.1   Introduction and Features of the Module

This module is an examination of the stages in undertaking empirical research involving analysis by multilevel modelling. Some important issues arising at each step in the whole process are addressed, starting with the formulation of research questions in need of answers. Important subsequent steps are associated with the management of a suitable raw data set. When those data have a multilevel structure, appropriate strategies for building multilevel models are examined which seek to answer the initial specific research questions. The process of the research will then involve using that modelling framework to elaborate on and further refine these questions.

All the discussion is contextualised by a focus on a particular research area: ethnic differences in educational achievement and progress. Some basic initial questions in that area are approached. These are stimulated by reviewing the literature and some exploratory initial data analysis. Replication, amplification and also extension of existing knowledge in some newer contexts are then sought.

The dataset used for analysis in the module is then introduced. It is a two-level dataset which is available to the author from previous research. It organises information on a cohort of pupils in an English region completing Key Stage 3 (KS3) in 2003 and on secondary schools which they attend. [1]

After a discussion of some essential aspects of data preparation there is then a move to analysis by multilevel modelling. It is aimed to show how, by using

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[1] In England children attending a state school from ages 11 to 14 (Years 7 to 9) follow Key Stage 3 of the National Curriculum. National tests are taken in a variety of areas at the end of this Key Stage to monitor children's achievements. Similarly Key Stage 2 (KS2) covers primary school stages of learning Years 3 to 6 and is assessed by end of KS2 tests just before transition to secondary schooling.

various aspects of the modelling procedures introduced in previous modules, research can be progressed in a strategic way both in addressing initial research questions and then refining them. Through careful analysis, the data may suggest interesting and meaningful modifications to these initial questions.

In summary, the discussion centres on what a practical researcher might do in planning and executing a piece of investigative research in which multilevel modelling has a critical role.

Particular features of the module are:

- Framing the initial research questions;
- How does a multilevel structure affect the management of a dataset?
- Checking the data set and getting familiar with its features;
- Building in essential features to exploit its multilevel nature;
- Data management and transformation to make it amenable to answering the questions of interest, including:
  - Recoding;
  - Creating new variables and in particular level 2 variables as aggregates of individual level variables;
  - Merging data from several sources, e.g. school level or neighbourhood variables;
  - Identifying and knowing about missing values;
  - Initial exploratory analyses and possible feedback to the research questions;
  - Tentative initial modelling strategies and reshaping research questions;
  - Working towards a series of models to address the research questions in a strategic way.

In summary the aims of the module are to describe:

The process of doing empirical research with multilevel models warts and all — from a rough data set to a polished end result.

8.2   Framing the Initial Research Questions

8.2.1   The initial context: results on Key Stage 3 for the West Midlands

The focus of this module is ethnic group differences in KS3 achievements at secondary school and progress up to KS3. Much of the previous work in this field has been on the primary stage of education or terminal stages of compulsory secondary education at age 16 (end of Key Stage 4). Mathematics achievement is studied as an exemplar although other outcomes could have been examined.

To contextualise the issues we begin by carrying out some basic descriptive analysis to explore the distribution of children by ethnic group, and to summarise the distribution of KS3 achievement by ethnic group. This might help to sharpen insights and highlight specific foci for our research. Table 8.1 presents this summary of KS3 mathematics test results for 32232 children attending local education authority schools in 2003 in the West Midlands region. The raw scores have been normalised[2] across KS3 for England as a whole, so they have a mean of zero (corresponding to the national mean) and a standard deviation of one. Ethnic group is classified into 19 groups which is the finest categorisation available in this dataset. The rows of Table 8.1 are ordered by the code number of group in the official dataset, but the criterion effectively gives a broad grouping: White groups, then those with Mixed ethnicity, followed by Asian (except Chinese), Black, and finally other smaller groups including Chinese. The numbers and percentage distribution across the groups are given together with the mean and standard deviations of KS3 scores for pupils within each group. The final column gives in addition the standard error of the mean, which is a measure of how precisely the mean is estimated.[3] When the mean of a group is divided by the standard error this gives a Z statistic which may be referred to a normal distribution to test whether that group differs significantly from the national mean of zero.

Some key features of Table 8.1 may be noted:

- Chinese pupils do well. Even though their number is small, when the precision of the estimate of the mean is considered, they are still quite significantly above the national average score of zero.

- Students from the three black groups do not perform well and are all significantly below average.

- Amongst the main South Asian groups Indians do much better than average (and hence better than the large majority White group), whereas Pakistani and Bangladeshi achievements are much lower. The mean score of the Any Other Asian group is similar to that of Indians.

- Most Mixed Ethnicity groups have lower than average scores except for

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[2] See Section 8.5 for a discussion of normalisation.
[3] See Module 2, C2.5.2.

Mixed White and Asian but this group is not significantly above the average.

Table 8.1 Normalised KS3 Mathematics (ks3matn) results for students in West Midlands local education authorities

Ethnic Group	Number	%	Mean Ks3matn	SD	St Err of the Mean
White British	22744	70.6	0.04	0.98	0.006
Irish	236	0.7	0.09	1.025	0.067
Irish Traveller	4	<0.05	0.39	1.215	0.608
Roma	4	<0.05	-0.36	1.314	0.657
Other White	393	1.2	0.04	1.060	0.053
Mixed White and Black Caribbean	572	1.8	-0.31	0.917	0.038
Mixed White and Black African	57	0.2	-0.84	0.888	0.118
Mixed White and Asian	197	0.6	0.11	1.046	0.075
Any other mixed background	342	1.1	-0.21	1.014	0.055
Indian	2260	7.0	0.17	0.985	0.021
Pakistani	2007	6.2	-0.36	1.032	0.023
Bangladeshi	444	1.4	-0.28	0.954	0.045
Any Other Asian	196	0.6	0.26	1.144	0.082
Black Caribbean	973	3.0	-0.45	0.928	0.030
Black African	82	0.3	-0.21	0.964	0.106
Any other Black background	144	0.5	-0.25	0.941	0.078
Chinese	103	0.3	1.26	1.015	0.101
Any other background	154	0.5	0.02	1.181	0.095
Unclassified /Missing	1320	4.1	-0.03	0.989	0.027
ALL WEST MIDLANDS	32232	100.0	0.00	0.996	0.006

Specific questions are now motivated, and we focus on framing plausible explanations and hypotheses about the ethnic group differences observed. However, before this point is reached, any empirical research will also usually be guided by a search of existing research literature. This may point to lines of enquiry that may be fruitful, or also prevent research going along unpromising tangential lines that initially may have seemed promising.

8.2.2   Background literature

There are considerable contributions in the research literature related to the topic we have chosen.[4] Examination of this contributes to the initial questions to be examined which are outlined in the next section. Almost all the most recent work on English education uses the National Pupil Database (NPD) and the Pupil Level Annual School Census (PLASC)[5] from which Table 8.1 and the data used in this module are also drawn.

The patterns observed in Table 8.1 on achievement at KS3 are reflected to varying extents at other stages in education, at various times, for different regions and nationally. For instance Wilson et al (2006), on achievement at age 16 say, '*We confirm that in the high stakes exams taken at age 16, pupils from some ethnic groups achieve considerably lower scores than white pupils on average: pupils with Black Caribbean heritage, other Black heritage or Pakistani ethnicity. Students with Indian or Chinese ethnicity score much higher than their white peers'*. Melluish et al (2006) make broadly comparable statements for primary education Key Stage 2 (KS2) achievement across different KS2 tests, and for two adjacent years, 2003 and 2004.

There are recurrent themes arising in this literature which prompt the search for the explanations that will form the focus of this module. A major concern is not with achievement at a given level but with progress from a previous educational stage to that level. An examination of this will require some control for educational achievements at earlier stages. The question then arises as to whether the 'ethnic gaps' arising at various levels widen or narrow as children progress through schooling: taking initial starting points into account, are progressions to later achievements greater for some ethnic groups than others? Dustmann et al (2008) say for example, '*From Key Stage 1 to Key Stage 2 most ethnic minority groups catch up, or in the case of Chinese and Indian pupils, even overtake White British pupils, in both English and Mathematics. The catch-up (or overtaking) is most striking for Bangladeshi and Chinese pupils, for whom the gain exceeds 20% of a standard deviation. The only group for which we do not observe a narrowing of the achievement gap in primary school is Black Caribbean pupils. For this group, both the English and Mathematics test score gap widened by about 6% of a standard deviation over a 4 year period'*. The research literature then suggests that patterns of progress are a fruitful line of enquiry. The concentration here will be on the different area of progress from Key Stage 2 up to Key Stage 3, where the latter is measured by the Mathematics outcome.

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[4] Examples, full details of which are given in the References section at the end of the Module, include Amin et al. (1997), Archer and Francis (2007), Bradley & Taylor (2004), Cassen & Kingdon (2007), Demie (2001), Department for Education and Skills (2006), Drew & Fosum (1994), Dustmann et al (2008), Gillborn & Mirza (2000), Melhuish et al (2006), Modood (2003), Plewis (1988), Verma & Ashworth (1986), and Wilson et al (2006). All these relate mainly to the experience in England and Wales. A slightly dated review of the Scottish experience is Powney et al (1998). There is an also a large literature on the US experience which is reviewed by Neal (2006).
[5] Full details of these may be found on the PLASC/NPD Users' Group website hosted by the University of Bristol: http://www.bristol.ac.uk/cmpo/plug/

A major pre-occupation of previous analyses has been to explore plausible explanations for ethnic group differences in achievement or progress. For instance other socioeconomic characteristics which influence educational outcomes, and which are also related to ethnicity, may mediate ethnic differences in outcomes. Dustmann et al (2008), for example, propose examining the impact of controlling for two family characteristics in the data available to them: poverty as measured by whether the child is eligible for free school meals, and whether English is the child's first language. In a similar vein Wilson et al (2006) use these and also gender, Special Educational Needs (SEN) status and age in saying, '*We show that, controlling for a small set of personal characteristics, all ethnic minority groups make greater progress on average than white students between ages 11 and 16. For some groups, this relative progress is substantial. During the period of secondary schooling, pupils from all groups are either catching up with white pupils (Black Caribbean or other Black heritage), or overtaking white pupils (Indian, Pakistani, Bangladeshi ethnicities or Black African heritage). The counterpart of this finding is that the group with the most problematic path through secondary schooling is disadvantaged white boys*'.

School effects on children's achievement and progress are of particular interest, and require the use of a multilevel data set and multilevel modelling techniques. Cassen and Kingdon (2007), for example, say '*Schools do make a difference to outcome. While students' social and economic importance are the most important factors explaining their educational results, we find that about 14 per cent of the incidence of low achievement is attributable to school quality (sic)*.' Similar conclusions about the role of schools are also made in the range of other literature cited.

The research literature also suggests other relevant and key issues. There are assertions in the literature that ethnic differences in progress exhibit different patterns for girls and boys. There may then be interactions between gender and ethnicity. Not exploring this and other interactions may lead to interesting issues being obscured. There has also been investigation of how the relationship between outcomes and prior achievements may differ for different ethnic groups. If ethnicity moderates the predictive effect of previous achievement (i.e. there is an interaction between ethnicity and previous achievement), it may obscure important aspects of differential progress of ethnic groups. The literature also hints that that there may be marked variations between schools, not only in overall progress of their pupils but also in the sizes of ethnic gaps in progress at various levels. These may be related to different characteristics of schools.

8.2.3   Initial research questions

General issues

The previous two sections briefly illustrate a typical scenario faced by a researcher now contemplating empirical approaches in the research area of interest. The initial motivation may have been interest in the area in a broad sense, but steps have been taken to undertake preliminary investigations to give specific direction to the inquiry. A literature review is an almost inevitable part of this. Sometimes,

but not always, there is a set of data at hand which may have been part of the motivation. In this case very preliminary explorations of those data (as in Table 8.1) may be useful. In other cases decisions on what data may be gathered or used may come after the research questions have been narrowed down. This aspect will not be discussed in this module but it is often a necessary part of the process.[6]

After these preliminary investigations have taken place, the researcher is then better placed to give some focus to the work in the form of some initial research questions. Before these are framed the following general considerations may be noted:

Initial questions should be simple and specific since this gives direction to initial stages of data analysis; otherwise undirected analysis may be inefficient and confusing.

These initial questions may be refined as the research evolves through exploratory analysis of data and further evaluation of the literature.

- Unless tight controls or design conditions have been established for causal attributions to be made, care must be taken in framing questions and interpreting their answers. Dustmann et al (2008), for example, say '*It is important to stress that the impact of poverty and language ability on test scores should be interpreted as an association only and not as a causal relationship*'. A similar caveat applies in this module when words such as 'impact', 'explain', 'effect' or 'influence' are used. The transformation of plausible causal explanations (which such words might be taken to imply) into causal statements is beyond the scope of this module.

Specific questions

From our preliminary analysis (Table 8.1) and initial review of the literature, we identify the following questions as a framework to the analysis that follows:

- Q1: Are there any structural features of the education system, such as differences in achievement levels between local education authorities or types of school, of which we should take account before looking at effects of ethnicity?

- Q2: How do differences between various ethnic groups in KS3 Mathematics achievement change when we adjust for KS2 achievements, and hence consider progress from KS2?

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[6] Sometimes the investigator has *ab initio* to design an experiment or conduct a sample survey to be able to conduct empirical investigations. In recent years there is greater reliance on the use of data previously collected for other purposes which is made available to researchers for further analysis. It is from this position we start in this module since we deal with datasets that are available from official statistics sources. The UK Data Archive at http://www.data-archive.ac.uk/ has an extremely large collection of social science datasets which are available to researchers who may wish to see what is available and suitable for their research prior to them thinking about initiating their own primary data collection.

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