Day 1: Introduction to multi-level data problems

Introduction to Multilevel Models
EUI Short Course 22–27 May, 2011
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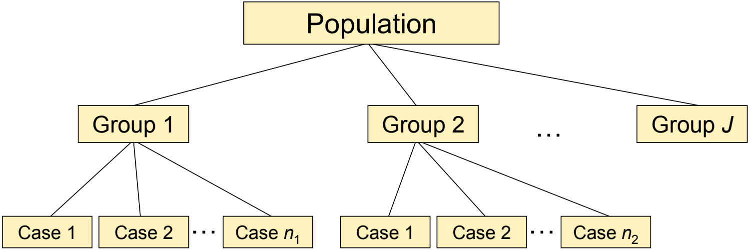
Course logistics and overview

- Purpose of the course
  - introductory
  - basic mathematical understanding of MLMs
  - applied, emphasis on Stata
  - Day 5 covers a few non-linear models
- What we will not do
  - work with really complicated multi-level structures
  - deal with estimation issues
  - use Bayesian methods
- Further caveats
- Texts and how to use them
- Software and datasets
- Homework format, timing
- Overview of other course logistics

What is multilevel data?

- Multilevel data comes from a data structure in the population that is hierarchical, with sample data consisting of a multistage sample from this population
- The classic example is schools and pupils: first we take a sample of schools, then sample pupils within each school
- We would then say that pupils are *nested* within schools
- Other examples:
  - individuals nested within countries (survey data)
  - experts nested within countries (expert survey data)
  - coded documents nested within coders (Comparative Manifesto Project)
  - political parties within national contexts
- Variables may vary at either level
- Basic terminology: lowest level is Level 1, higher is Level 2
- Response variables (Y) always vary at the lowest level

The structure of multilevel data



- a variation on this is *longitudinal* data structure, where the level 1 variable is an observation for a given time, and the level 2 variable is a subject
- nesting may be *unintentional*: for instance we could have policy categories from manifestos (level 1) coded by coder (level 2); or survey respondents (level 1) nested within interviewer (level 2)
- terminology may vary — here we refer to *multilevel models* generically but terms found in the literature include: variance components models, random-coefficients models and random-effects models, (general) mixed models, and hierarchical linear models

Why would special models be needed for multilevel data?

- The usual assumptions for causal inference from regression models is that individual observations are independent
- With nested structures this may not be the case: the correlation between observations within a common unit will be higher than the average correlation of observations between units
- Consequence is that we will underestimate the uncertainty of causal effects from pooled estimates
- In addition, only multilevel models can help us separate within-unit from between-unit effects, especially the different average effects and the different effects of covariates

The ecological fallacy

- The ecological fallacy refers to the fallacy of inferring individual behavior from aggregate data – in our context, inferring Level 1 relationships based on Level 2 units
- Arises when level 2 variables and level 1 variables reflect different causal processes
- originally from Robinson (1950) who studied the relationship between literacy and race in the US. The correlation between mean literacy rates and mean proportions of the black population was 0.95, but the individual-level correlation ignoring the grouping was just is 0.20
- A problem in many political research questions, esp. voting behavior inferred from aggregated results

The atomistic fallacy

- The atomistic fallacy (aka *individualistic fallacy*) may occur when drawing inferences about group-level relationships from individual-level data
- Arises because individual-level associations associations may differ of those at the group level
- Example: we might find that individual income is positively associated with decreased mortality from heart disease. From this we should not infer, howeer, that at the country level, increasing per capita income is associated with decreasing heart disease mortality. In fact, across countries we might actually increase heart disease mortality by increasing income.

Stata and “robust” clustered standard errors”

- One method of correcting for the effect of clusters is to specify the `vce(cluster` *`clustvar`*`)` as an option to regression commands
- This relaxes the requirement that the errors be independent, by allowing them to be correlated within each cluster group
- The correction only affects the standard errors, not the estimated coefficients, since it operates only on the variance-covariance matrix
- This will not get at the core issues of interest for multilevel models, which have to do with separating between-group effects from within-group effects, and especially not the provision for random intercepts and or slopes

The organization of multilevel data

- Multilevel data are distinguished by their organization according to multilevel identifying units. Examples:
  - constituency ID
  - country ID
  - school ID
- There are two basic formats for organizing data that are clustered by identifying units:

  wide format two columns of data contain the same information, distinguished by different levels

  long format different levels are themselves variables (in their own columns

Zen and the art of `reshapeing`

- some things cannot be done in long format. For instance if we want to plot one set of scores against another, e.g. taxes v. spending versus social dimension from the expert surveys
- For this we need the wide format, where each dimension forms a separate variable and the identifier defines a unique row
- To convert from long to wide (and vice versa), we need the `reshape` command
- The key to using reshape is to determine what the logical observation i is and the subobservation j that will be used to organize the data

Zen and the art of `reshapeing` continued

```
         (wide form)
i        ....... x_ij ........
id  sex   inc80   inc81   inc82
-------------------------------
 1    0    5000    5500    6000
 2    1    2000    2200    3300
 3    0    3000    2000    1000
```

```
      (long form)
i     j          x_ij
id   year   sex   inc
-----------------------
 1    80     0   5000
 1    81     0   5500
 1    82     0   6000
 2    80     1   2000
 2    81     1   2200
 2    82     1   3300
 3    80     0   3000
 3    81     0   2000
 3    82     0   1000
```

```
Given this data, you could use reshape to convert from one form to the other:

    . reshape long inc, i(id) j(year)  (goes from top-form to bottom)
    . reshape wide inc, i(id) j(year)  (goes from bottom-form to top)
```

Example of multilevel data: Benoit and Marsh (2008)

```
. use dail2002spending
(Irish Dail 2002 from Benoit and Marsh 2008)

. list constID constituency namelast party votes1st incumb m spent in 6/28, clean

      constID       constituency     namelast   party   votes1st   incumb   m      spent
  6.        1   Carlow Kilkenny   McGuinness      ff       9343        1   5    19648.3
  7.        1   Carlow Kilkenny        Nolan      ff       8711        0   5   24100.27
  8.        1   Carlow Kilkenny        Nolan     ind        335        0   5    6544.23
  9.        1   Carlow Kilkenny      O'Brien     lab       3732        0   5    8404.43
 10.        1   Carlow Kilkenny     Townsend     lab       4272        0   5   10658.21
 11.        1   Carlow Kilkenny        White      gp       4961        0   5   12110.11
 12.        2    Cavan Monaghan      Boyland      fg       4819        1   5   11217.01
 13.        2    Cavan Monaghan      Brennan     ind       1026        0   5   17196.73
 14.        2    Cavan Monaghan     Connolly     ind       7722        0   5   17934.79
 15.        2    Cavan Monaghan     Crawford      fg       6113        1   5      11124
 16.        2    Cavan Monaghan       Cullen     lab        550        0   5    8756.67
 17.        2    Cavan Monaghan    Gallagher      ff       3731        0   5   20122.19
 18.        2    Cavan Monaghan       Martin     ind       1943        0   5   34542.73
 19.        2    Cavan Monaghan       McCabe      gp       1100        0   5   10699.87
 20.        2    Cavan Monaghan    McCaughey      pd       1131        0   5   30573.12
 21.        2    Cavan Monaghan    O Caolain      sf      10832        1   5   28953.32
 22.        2    Cavan Monaghan     O'Hanlon      ff       7204        1   5   21483.37
 23.        2    Cavan Monaghan     O'Reilly      fg       4639        0   5    12839.2
 24.        2    Cavan Monaghan        Smith     csp        358        0   5    3141.27
 25.        2    Cavan Monaghan        Smith      ff      10679        1   5   22383.53
 26.        3             Clare        Breen      fg       4541        0   4   11687.46
 27.        3             Clare        Breen     ind       9721        0   4   11974.15
 28.        3             Clare        Carey      fg       4015        1   4   14195.46
```

Benoit and Marsh (2008) example continued

```
. desc

Contains data from dail2002spending.dta
  obs:           463                          Irish Dail 2002 from Benoit and Marsh 2008
 vars:            10                          18 May 2009 17:45
 size:        26,854 (99.9% of memory free)
-------------------------------------------------------------------------------
              storage  display     value
variable name   type   format      label      variable label
-------------------------------------------------------------------------------
constID         byte   %9.0g                  Constituency Numeric ID
constituency    str20  %20s                   Candidate's constituency
namelast        str15  %15s                   Candidate's last name
party           byte   %8.0g       party_e    Candidate's party label
votes1st        int    %9.0g                  First preference votes 2002
incumb          byte   %9.0g                  Incumbency status 1/0
wonseat         byte   %9.0g                  Candidate won a seat 1/0
m               byte   %9.0g                  District magnitude
electorate      float  %9.0g                  Registered voters in constituency
spent           float  %9.0g                  Total spending
-------------------------------------------------------------------------------
Sorted by:  constID  namelast
```

Constitituency-level `m`, `electorate`

Candidate-level `namelast`, `votes1st`, `incumb`, `wonseat`, `spent`, `party`
(and we could view `party` as having a special status)

Long v. wide data format: *PPMD* example

```
. use PPMD_detail, clear
(Party Policy in Modern Democracies, Kenneth Benoit and Michael Laver)

. sample 20, count
(206945 observations deleted)

. list Country Party Dimension Scale Survey_Label_ID Score Vote_Share Election_Date, clean

       Country     Party              Dimension        Scale   Survey~D   Score   Vote_S~e   Electi~e
  1.        SE        MP     Taxes v. Spending     Position        408      11        4.6       2002
  2.        ES       CiU     Taxes v. Spending     Position        191      12        3.2       2004
  3.        SE         M      EU: Peacekeeping     Position        892       5       15.2       2002
  4.        DE   CDU/CSU      EU: Peacekeeping   Importance       1689       3      38.51       2002
  5.        MD      PDAM           Environment   Importance         12       6        1.9       2001
  6.        SI       SNS           Urban-Rural   Importance         44      16        4.4       2000
  7.        NO       KrF     NATO/Peacekeeping     Position         74       8       12.5       2001
  8.        FR       UDF     Taxes v. Spending   Importance         16      14        4.8       2002
  9.        SR       DSS            Left-Right     Position          1      13         18       2003
 10.        CA       LPC              Sympathy     Position        820      17       40.8       2000
 11.        JP       JCP        Defense policy   Importance          3       5        7.7       2003
 12.        CA       GPC              Sympathy     Position        437       7         .8       2000
 13.        RO        PD                Social     Position        574       6       7.03       2000
 14.        HU     MUNKS         Media Freedom   Importance        823      19        2.8       2002
 15.        IL      Merz    Palestinian State   Importance        543      20        5.2       2003
 16.        DE       GRU      EU: Peacekeeping   Importance       1262      13        8.6       2002
 17.        IT       SDI          Deregulation   Importance        120      14        1.1       2001
 18.        BE        PS           Environment     Position        547      10         13       2003
 19.        IT       UDC    EU: Accountability   Importance        189      12        3.2       2001
 20.        CZ        SZ                Social     Position         31      12       2.36       2002
```

Long v. wide data format: *PPMD* example

- The PPMD dataset is organized as long data, where the basic unit of variation is the `Score` variable
- `Score` represents the placement on a 1–20 point scale of either the left-right location or the low–high importance
- The different variables are:

Country	a code designating the country
Party	a country-specific alphanumeric identifier for party
Dimension	one of 40-odd policy dimensions
Scale	either Position or Importance
Survey_Label_ID	country-specific respondent ID

- This is a useful way to *store* the data, but may not be useful for analyzing it, although this depends

Long v. wide data format: *PPMD* example continued

For data analysis based on tables, the long format is required. Example:

```
. use PPMD_detail, clear
(Party Policy in Modern Democracies, Kenneth Benoit and Michael Laver)

. table Party Dimension if Country=="IT":cntryLab & Scale==1 & Dimension<15, c(mean Score) format(%9.1f)
```

Party abbreviation	Policy dimension: Taxes v. Spending	Social	Environment	Decentralization	Left-Right
AN	10.1	18.3	13.5	14.9	16.9
DS	6.7	5.0	7.3	7.4	6.0
FI	17.5	12.9	17.2	8.9	15.6
Green	4.9	3.4	1.7	9.5	4.0
It.Val.	8.6	9.9	8.3	9.1	10.1
LN	15.1	17.1	15.3	2.4	16.9
MSFT	6.7	18.5	10.7	16.2	19.0
Marg	8.5	11.9	8.3	8.1	8.0
PDCI	3.9	4.2	6.4	12.5	3.3
Pann	15.2	2.0	9.3	6.8	12.0
RC	2.9	3.7	5.6	13.4	2.1
SDI	9.3	7.1	9.6	8.9	8.6
UDC	10.6	16.0	11.7	10.5	12.4

Long v. wide data format: *PPMD* example continued

```
. table Country Dimension if Dimension<5 & Country>60
```

Country name	Policy dimension: Taxes v. Spending	Social	EU joining
GR	127	128	
IS	144	144	
IE	626	632	
IL	668	682	
IT	1,189	1,196	
LU	48	47	
MT	35	38	38
NL	387	387	
NZ	301		
NI	152	154	
NO	330	333	336
PT	246	243	
ES	753	751	
SE	937	936	
CH	934	956	897
TR	412	411	423
US	662	662	
EU	273	287	
JP	696	696	

Long v. wide data format: *PPMD* example continued

For data analysis based on tables, the long format is required. Example:

```
. ttest Score if Dimension>13, by(Scale)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
Position |   39587    10.65799    .0292697    5.823644    10.60062    10.71536
Importan |   30031    12.98175    .0274553     4.75786    12.92794    13.03557
---------+--------------------------------------------------------------------
combined |   69618    11.66039    .0208877    5.511278    11.61945    11.70133
---------+--------------------------------------------------------------------
    diff |           -2.323758    .0412452               -2.404599   -2.242918
------------------------------------------------------------------------------
    diff = mean(Position) - mean(Importan)                        t = -56.3401
Ho: diff = 0                                     degrees of freedom =    69616

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

Reshape example with expert survey data

```
. reshape wide Score, i(Country Survey_Label_ID Party Vote_Share Scale) j(Dimension)
(note: j = 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35

Data                               long   ->   wide
-----------------------------------------------------------------------------
Number of obs.                   206970   ->   21029
Number of variables                  12   ->      50
j variable (40 values)        Dimension   ->   (dropped)
xij variables:
                                  Score   ->   Score1 Score2 ... Score99
-----------------------------------------------------------------------------

. list Country Party Scale Survey_Label_ID Vote_Share Score1-Score4 in 1/10, clean

       Country   Party        Scale   Survey~D   Vote_S~e   Score1   Score2   Score3   Score4
  1.        AL   PBDNJ     Position          1        2.6        9        9        9       14
  2.        AL   PBDNJ   Importance          1        2.6        4        1        3       17
  3.        AL      PD     Position          1      19.36       12        9       15       17
  4.        AL      PD   Importance          1      19.36       16        4       15       17
  5.        AL     PDr     Position          1        5.1       13        9       15       17
  6.        AL     PDr   Importance          1        5.1       16        6       15       17
  7.        AL     PLL     Position          1       4.03       14       11       15       17
  8.        AL     PLL   Importance          1       4.03       14        4       15       17
  9.        AL      PR     Position          1       4.83       13       11       15       17
 10.        AL      PR   Importance          1       4.83       16        4       16       17
```

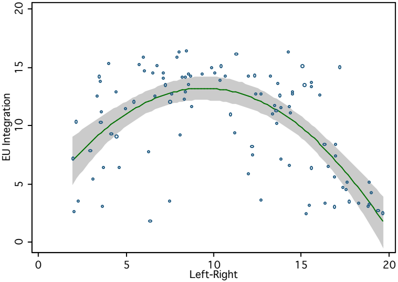
Reshape example with expert survey data

```
. use PPMD_summary_day1, clear
(Party Policy in Modern Democracies, K. Benoit and M. Laver, Summary Data)

. reshape wide Mean, i(Country Party Scale) j(Dimension)
(note: j = 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 36 37

Data                               long   ->   wide
-----------------------------------------------------------------------------
Number of obs.                     8106   ->    739
Number of variables                   8   ->     44
j variable (38 values)        Dimension   ->   (dropped)
xij variables:
                                   Mean   ->   Mean1 Mean2 ... Mean99
-----------------------------------------------------------------------------

. graph twoway (qfitci Mean24 Mean13) (scatter Mean24 Mean13, msize(small) m(oh)) if Scale==1,
> xtitle(Left-Right) ytitle(EU Integration) legend(off)
```



Introducing variance decomposition models

- Standard model without covariates:

$$y_{ij} = \beta + \xi_{ij}$$

- We can model the dependence within subjects j by splitting ξ_{ij} into two components ζ_j and ϵ_{ij}:

$$y_{ij} = \beta + \zeta_j + \epsilon_{ij}$$

- ζ_j represent level-2 effects, also known as "random intercepts", with variance ψ:

$$\zeta_j \sim N(0, \psi)$$

- ϵ_{ij} are level-1 errors, with variance θ

$$\epsilon_{ij} \sim N(0, \theta)$$

- More complicated models will be explored later, such as random coefficients (involving β differences at level-2)