**SOCY7708: Hierarchical Linear Modeling**

**Instructor: Natasha Sarkisian**

**Class notes: Cross-Nested Models**

In this unit, we will look at cross-nested (or cross-classified or cross-effects) models. These are models where lower-level units simultaneously belong to two higher-level units—these could be two units of the same type (for examine, two neighborhoods where a person lived at different periods of time or two schools that they attended) or two units of different type (e.g., neighborhoods and schools).

For our first example, we will use data from a study of neighborhood and school contribution to educational attainment in Scotland (as used in the *Hierarchical Linear Models* textbook by Raudenbush and Bryk, 2002). We will use attain.dta file from the website; it contains data on individuals nested in neighborhoods (N=542) and schools (N=17) in such a way that people from the same neighborhood can be attending different schools, so three-level model is not possible. Here, we have to have two IDs, one for each higher-level unit – SCHID and NEIGHID.

The variables available on level 1 are:

* ATTAIN, a measure of educational attainment
* P7VRQ, denoting primary 7 verbal reasoning quotient
* P7READ, denoting primary 7 reading test scores
* DADOCC, indicating the father’s occupation scaled on the Hope-Goldthorpe scale in conjunction with the Registrar General’s social-class index
* DADUNEMP, an indicator for father’s unemployment status (1 if unemployed, 0 otherwise)
* DADED, an indicator for father’s educational level (1 if schooling past the age of 15, 0 otherwise)
* MOMED, an indicator for mother’s educational level (1 if schooling past the age of 15, 0  otherwise)
* MALE, an indicator for student gender (1 if male, 0 if female)

A variable at neighborhood level is:

* DEPRIVE, an index of social deprivation for the local community where the respondent lived

We do not have any variables on school level but we could aggregate level 1 variables to create such aggregated measures.

First, how many different neighborhoods do people in specific schools come from, and how many different schools do people in a given neighborhood attend? Let’s count:

. use attain.dta, clear

. sort neighid schid

. bysort neighid schid: gen num=\_n

. gen count=(num==1)

. bysort neighid: egen schoolsinneigh=total(count)

. egen neightag=tag(neighid)

. tab schoolsinneigh if neightag==1

schoolsinne |

 igh | Freq. Percent Cum.

------------+-----------------------------------

 1 | 309 58.97 58.97

 2 | 176 33.59 92.56

 3 | 33 6.30 98.85

 4 | 6 1.15 100.00

------------+-----------------------------------

 Total | 524 100.00

. bysort schid neighid: gen n=\_n

. gen countn=(n==1)

. bysort schid: egen neighperschool=total(countn)

. egen schtag=tag(schid)

. tab neighperschool if schtag==1

neighpersch |

 ool | Freq. Percent Cum.

------------+-----------------------------------

 11 | 1 5.88 5.88

 29 | 1 5.88 11.76

 31 | 1 5.88 17.65

 37 | 1 5.88 23.53

 40 | 1 5.88 29.41

 41 | 1 5.88 35.29

 42 | 2 11.76 47.06

 43 | 1 5.88 52.94

 46 | 1 5.88 58.82

 47 | 1 5.88 64.71

 52 | 2 11.76 76.47

 53 | 1 5.88 82.35

 61 | 1 5.88 88.24

 65 | 1 5.88 94.12

 92 | 1 5.88 100.00

------------+-----------------------------------

 Total | 17 100.00

To estimate a cross-nested model in Stata, we use a work-around solution creating a “fake” three level model, wherein individuals are nested in neighborhoods which are then nested in an entire set but with random effects for dummy variables for schools which have their variances constrained to the same number and covariances constrained to zero. That effectively gives us two variances, one for each level. Therefore, for schools, we use specification \_all: R.schid.

. mixed attain || \_all: R.schid || neighid:

Mixed-effects ML regression Number of obs = 2,310

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 2,310 2,310.0 2,310

 neighid | 524 1 4.4 16

-------------------------------------------------------------

 Wald chi2(0) = .

Log likelihood = -3178.3557 Prob > chi2 = .

------------------------------------------------------------------------------

 attain | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 \_cons | .0753532 .0722216 1.04 0.297 -.0661987 .216905

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.schid) | .075445 .0316491 .0331553 .1716755

-----------------------------+------------------------------------------------

neighid: Identity |

 var(\_cons) | .1412201 .0218651 .104257 .191288

-----------------------------+------------------------------------------------

 var(Residual) | .7990182 .0263652 .7489788 .8524007

------------------------------------------------------------------------------

LR test vs. linear model: chi2(2) = 207.44 Prob > chi2 = 0.0000

Note: LR test is conservative and provided only for reference.

We could use these variance components to calculate the percentage of variance due to each level of nesting; alternatively, to get a rough sense, I will estimate two two-level models and get their ICC:

. mixed attain || neighid:

Mixed-effects ML regression Number of obs = 2,310

Group variable: neighid Number of groups = 524

 Obs per group:

 min = 1

 avg = 4.4

 max = 16

 Wald chi2(0) = .

Log likelihood = -3207.9847 Prob > chi2 = .

------------------------------------------------------------------------------

 attain | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 \_cons | .0820248 .0284356 2.88 0.004 .0262921 .1377575

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

neighid: Identity |

 var(\_cons) | .2015382 .0257242 .1569317 .2588237

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 var(Residual) | .8043706 .0265743 .7539364 .8581785

------------------------------------------------------------------------------

LR test vs. linear model: chibar2(01) = 148.18 Prob >= chibar2 = 0.0000

. estat icc

Intraclass correlation

------------------------------------------------------------------------------

 Level | ICC Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

 neighid | .2003543 .0223053 .1601713 .2476457

------------------------------------------------------------------------------

. mixed attain || schid:

Mixed-effects ML regression Number of obs = 2,310

Group variable: schid Number of groups = 17

 Obs per group:

 min = 22

 avg = 135.9

 max = 286

 Wald chi2(0) = .

Log likelihood = -3221.0818 Prob > chi2 = .

------------------------------------------------------------------------------

 attain | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 \_cons | .0822691 .0756785 1.09 0.277 -.0660581 .2305963

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

schid: Identity |

 var(\_cons) | .0887424 .0348585 .0410937 .1916405

-----------------------------+------------------------------------------------

 var(Residual) | .9344115 .0276055 .8818425 .9901144

------------------------------------------------------------------------------

LR test vs. linear model: chibar2(01) = 121.98 Prob >= chibar2 = 0.0000

. estat icc

Intraclass correlation

------------------------------------------------------------------------------

 Level | ICC Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

 schid | .0867342 .0312367 .0420038 .1706151

------------------------------------------------------------------------------

Let’s compare the model where school effects are estimated as constrained random effects of dummy indicators with the one where neighborhood effects are estimated that way. Typically, we select which variable we would like to specify as clusters within \_all depending on which one has fewer clusters because that will estimate faster. But also, if we want to have random slopes by cluster, we cannot specify that clustering variable within \_all (we will see that below).

. mixed attain || \_all: R.schid || neighid:

Mixed-effects ML regression Number of obs = 2,310

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 2,310 2,310.0 2,310

 neighid | 524 1 4.4 16

-------------------------------------------------------------

 Wald chi2(0) = .

Log likelihood = -3178.3557 Prob > chi2 = .

------------------------------------------------------------------------------

 attain | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 \_cons | .0753532 .0722216 1.04 0.297 -.0661987 .216905

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.schid) | .075445 .0316491 .0331553 .1716755

-----------------------------+------------------------------------------------

neighid: Identity |

 var(\_cons) | .1412201 .0218651 .104257 .191288

-----------------------------+------------------------------------------------

 var(Residual) | .7990182 .0263652 .7489788 .8524007

------------------------------------------------------------------------------

LR test vs. linear model: chi2(2) = 207.44 Prob > chi2 = 0.0000

Note: LR test is conservative and provided only for reference.

. mixed attain || \_all: R.neighid || schid:

Mixed-effects ML regression Number of obs = 2,310

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 2,310 2,310.0 2,310

 schid | 17 22 135.9 286

-------------------------------------------------------------

 Wald chi2(0) = .

Log likelihood = -3178.3557 Prob > chi2 = .

------------------------------------------------------------------------------

 attain | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 \_cons | .0753532 .0722216 1.04 0.297 -.0661987 .216905

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.neighid) | .1412201 .0218651 .104257 .191288

-----------------------------+------------------------------------------------

schid: Identity |

 var(\_cons) | .075445 .0316491 .0331553 .1716755

-----------------------------+------------------------------------------------

 var(Residual) | .7990182 .0263652 .7489788 .8524007

------------------------------------------------------------------------------

LR test vs. linear model: chi2(2) = 207.44 Prob > chi2 = 0.0000

Note: LR test is conservative and provided only for reference.

Let’s add level 1 predictors to our model:

. mixed attain p7vrq p7read dadocc dadunemp daded momed male || \_all: R.schid || neighid:

Mixed-effects ML regression Number of obs = 2,310

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 2,310 2,310.0 2,310

 neighid | 524 1 4.4 16

-------------------------------------------------------------

 Wald chi2(7) = 2415.24

Log likelihood = -2402.2937 Prob > chi2 = 0.0000

------------------------------------------------------------------------------

 attain | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 p7vrq | .02823 .0022758 12.40 0.000 .0237696 .0326904

 p7read | .0269051 .0017587 15.30 0.000 .0234581 .0303521

 dadocc | .0091773 .0013584 6.76 0.000 .0065148 .0118398

 dadunemp | -.1464694 .0469 -3.12 0.002 -.2383916 -.0545471

 daded | .1487033 .0410774 3.62 0.000 .068193 .2292136

 momed | .0649316 .0376491 1.72 0.085 -.0088593 .1387225

 male | -.0540241 .0285779 -1.89 0.059 -.1100358 .0019875

 \_cons | .0805349 .0272663 2.95 0.003 .027094 .1339758

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.schid) | .0030572 .0024765 .0006249 .0149566

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neighid: Identity |

 var(\_cons) | .0122113 .0072414 .0038194 .0390422

-----------------------------+------------------------------------------------

 var(Residual) | .4551568 .0148446 .4269722 .4852018

------------------------------------------------------------------------------

LR test vs. linear model: chi2(2) = 7.40 Prob > chi2 = 0.0248

Note: LR test is conservative and provided only for reference.

We can compare the variance components to the previous model; we see that much of school and neighborhood level variance has been explained. Let’s explore random slopes for level 1 predictors:

. mixed attain p7vrq p7read dadocc dadunemp daded momed male || \_all: R.schid || neighid: p7vrq p7read dadocc dadunemp daded momed male

Mixed-effects ML regression Number of obs = 2,310

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 2,310 2,310.0 2,310

 neighid | 524 1 4.4 16

-------------------------------------------------------------

 Wald chi2(7) = 2344.98

Log likelihood = -2400.0715 Prob > chi2 = 0.0000

------------------------------------------------------------------------------

 attain | Coef. Std. Err. z P>|z| [95% Conf. Interval]

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 p7vrq | .0282256 .0022713 12.43 0.000 .023774 .0326772

 p7read | .0268055 .0017535 15.29 0.000 .0233688 .0302422

 dadocc | .0089163 .0013768 6.48 0.000 .0062177 .0116149

 dadunemp | -.1460657 .0476964 -3.06 0.002 -.239549 -.0525824

 daded | .1524186 .0421274 3.62 0.000 .0698505 .2349868

 momed | .0620998 .0393571 1.58 0.115 -.0150386 .1392382

 male | -.05107 .0289833 -1.76 0.078 -.1078761 .0057362

 \_cons | .0773173 .0264105 2.93 0.003 .0255536 .129081

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.schid) | .0026377 . . .

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neighid: Independent |

 var(p7vrq) | 1.26e-22 . . .

 var(p7read) | 2.00e-22 . . .

 var(dadocc) | 8.74e-06 . . .

 var(dadunemp) | .0176157 . . .

 var(daded) | .0168711 . . .

 var(momed) | .0378511 . . .

 var(male) | .0115381 . . .

 var(\_cons) | .0086013 . . .

-----------------------------+------------------------------------------------

 var(Residual) | .4379232 . . .

------------------------------------------------------------------------------

LR test vs. linear model: chi2(9) = 11.84 Prob > chi2 = 0.2224

Note: LR test is conservative and provided only for reference.

. mixed attain p7vrq p7read dadocc dadunemp daded momed male || \_all: R.schid || neighid: dadocc dadunemp daded momed male

Mixed-effects ML regression Number of obs = 2,310

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 2,310 2,310.0 2,310

 neighid | 524 1 4.4 16

-------------------------------------------------------------

 Wald chi2(7) = 2344.97

Log likelihood = -2400.0715 Prob > chi2 = 0.0000

------------------------------------------------------------------------------

 attain | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 p7vrq | .0282256 .0022713 12.43 0.000 .023774 .0326771

 p7read | .0268055 .0017535 15.29 0.000 .0233688 .0302422

 dadocc | .0089163 .0013769 6.48 0.000 .0062177 .0116149

 dadunemp | -.1460655 .0476964 -3.06 0.002 -.2395488 -.0525823

 daded | .1524182 .0421275 3.62 0.000 .0698499 .2349866

 momed | .0621001 .0393571 1.58 0.115 -.0150384 .1392385

 male | -.0510699 .0289832 -1.76 0.078 -.1078759 .0057362

 \_cons | .077317 .0264105 2.93 0.003 .0255533 .1290807

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.schid) | .0026377 .0023525 .0004592 .0151495

-----------------------------+------------------------------------------------

neighid: Independent |

 var(dadocc) | 8.74e-06 .000039 1.41e-09 .054177

 var(dadunemp) | .0176157 .0348477 .0003648 .8506678

 var(daded) | .0168731 .0286061 .0006083 .4680537

 var(momed) | .0378509 .02812 .0088248 .1623482

 var(male) | .0115365 .0158341 .000783 .169969

 var(\_cons) | .008602 .007611 .0015186 .0487237

-----------------------------+------------------------------------------------

 var(Residual) | .4379224 .0169907 .405856 .4725225

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LR test vs. linear model: chi2(7) = 11.84 Prob > chi2 = 0.1059

Note: LR test is conservative and provided only for reference.

. mixed attain p7vrq p7read dadocc dadunemp daded momed male || \_all: R.schid || neighid: dadunemp daded momed male

Mixed-effects ML regression Number of obs = 2,310

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 2,310 2,310.0 2,310

 neighid | 524 1 4.4 16

-------------------------------------------------------------

 Wald chi2(7) = 2352.90

Log likelihood = -2400.0975 Prob > chi2 = 0.0000

------------------------------------------------------------------------------

 attain | Coef. Std. Err. z P>|z| [95% Conf. Interval]

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 p7vrq | .028238 .0022708 12.44 0.000 .0237873 .0326887

 p7read | .0267925 .0017535 15.28 0.000 .0233557 .0302294

 dadocc | .0089268 .0013663 6.53 0.000 .006249 .0116047

 dadunemp | -.1456732 .0477354 -3.05 0.002 -.2392329 -.0521135

 daded | .1526091 .0421365 3.62 0.000 .0700231 .2351951

 momed | .0619572 .0393694 1.57 0.116 -.0152055 .1391198

 male | -.0513633 .0289873 -1.77 0.076 -.1081773 .0054507

 \_cons | .0777818 .0264007 2.95 0.003 .0260375 .1295261

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.schid) | .0026311 .0023503 .0004569 .0151525

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neighid: Independent |

 var(dadunemp) | .0181434 .0348393 .0004209 .7820113

 var(daded) | .0173458 .0284977 .000693 .4341538

 var(momed) | .0383208 .0280697 .0091187 .1610401

 var(male) | .0116597 .015826 .0008153 .1667422

 var(\_cons) | .0087237 .0075905 .0015851 .0480106

-----------------------------+------------------------------------------------

 var(Residual) | .4386847 .0166627 .4072124 .4725893

------------------------------------------------------------------------------

LR test vs. linear model: chi2(6) = 11.79 Prob > chi2 = 0.0668

Note: LR test is conservative and provided only for reference.

We could do significance testing to see which slopes should be allowed to vary. We could also examine random slopes by school instead of neighborhoods – for that, we would reestimate it with \_all: R.neigh. But for the sake of time, let’s look at adding predictors on neighborhood and school level. Let’s aggregate:

. for var p7vrq - male: bysort neighid: egen X\_nei=mean(X)

-> bysort neighid: egen p7vrq\_nei=mean(p7vrq)

-> bysort neighid: egen p7read\_nei=mean(p7read)

-> bysort neighid: egen dadocc\_nei=mean(dadocc)

-> bysort neighid: egen dadunemp\_nei=mean(dadunemp)

-> bysort neighid: egen daded\_nei=mean(daded)

-> bysort neighid: egen momed\_nei=mean(momed)

-> bysort neighid: egen male\_nei=mean(male)

. for var p7vrq - male: bysort schid: egen X\_sch=mean(X)

-> bysort schid: egen p7vrq\_sch=mean(p7vrq)

-> bysort schid: egen p7read\_sch=mean(p7read)

-> bysort schid: egen dadocc\_sch=mean(dadocc)

-> bysort schid: egen dadunemp\_sch=mean(dadunemp)

-> bysort schid: egen daded\_sch=mean(daded)

-> bysort schid: egen momed\_sch=mean(momed)

-> bysort schid: egen male\_sch=mean(male)

. mixed attain p7vrq p7read dadocc dadunemp daded momed male deprive p7vrq\_nei

> p7read\_nei dadocc\_nei dadunemp\_nei daded\_nei momed\_nei male\_nei || \_all: R

> .schid || neighid: dadunemp daded momed male

Mixed-effects ML regression Number of obs = 2,310

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 2,310 2,310.0 2,310

 neighid | 524 1 4.4 16

-------------------------------------------------------------

 Wald chi2(15) = 2504.39

Log likelihood = -2373.3516 Prob > chi2 = 0.0000

------------------------------------------------------------------------------

 attain | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 p7vrq | .0260616 .0025478 10.23 0.000 .021068 .0310552

 p7read | .0262333 .0020008 13.11 0.000 .0223118 .0301549

 dadocc | .0060222 .0015824 3.81 0.000 .0029208 .0091236

 dadunemp | -.1094969 .0535435 -2.05 0.041 -.2144402 -.0045537

 daded | .1078427 .0468705 2.30 0.021 .0159782 .1997073

 momed | .0585125 .0440004 1.33 0.184 -.0277268 .1447517

 male | -.057422 .0320584 -1.79 0.073 -.1202553 .0054114

 deprive | -.1068588 .0289249 -3.69 0.000 -.1635506 -.0501669

 p7vrq\_nei | .0076765 .0054024 1.42 0.155 -.002912 .0182651

 p7read\_nei | -.0022259 .0040418 -0.55 0.582 -.0101477 .0056959

 dadocc\_nei | .006009 .0031406 1.91 0.056 -.0001465 .0121644

dadunemp\_nei | -.0782511 .109447 -0.71 0.475 -.2927633 .1362611

 daded\_nei | .1801198 .0970098 1.86 0.063 -.0100158 .3702555

 momed\_nei | -.0423525 .0895377 -0.47 0.636 -.2178431 .1331381

 male\_nei | .0428611 .0705518 0.61 0.544 -.0954179 .18114

 \_cons | .0505329 .0439281 1.15 0.250 -.0355646 .1366304

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 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.schid) | .0037432 .0025493 .0009852 .0142217

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neighid: Independent |

 var(dadunemp) | .0073473 .0328626 1.15e-06 47.13606

 var(daded) | .0115766 .0271607 .0001165 1.149878

 var(momed) | .0352373 .0264951 .008072 .1538242

 var(male) | .0103147 .0142086 .0006933 .1534618

 var(\_cons) | 8.08e-12 1.81e-11 9.89e-14 6.60e-10

-----------------------------+------------------------------------------------

 var(Residual) | .4387169 .0159951 .4084609 .4712139

------------------------------------------------------------------------------

LR test vs. linear model: chi2(6) = 10.55 Prob > chi2 = 0.1034

Note: LR test is conservative and provided only for reference.

. mixed attain p7vrq p7read dadocc dadunemp daded momed male deprive p7vrq\_sch

p7read\_sch dadocc\_sch dadunemp\_sch daded\_sch momed\_sch male\_sch || \_all: R.schid || neighid: dadunemp daded momed male

Mixed-effects ML regression Number of obs = 2,310

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 2,310 2,310.0 2,310

 neighid | 524 1 4.4 16

-------------------------------------------------------------

 Wald chi2(15) = 2554.09

Log likelihood = -2378.1708 Prob > chi2 = 0.0000

------------------------------------------------------------------------------

 attain | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 p7vrq | .0273469 .002274 12.03 0.000 .0228899 .0318038

 p7read | .0262508 .0017552 14.96 0.000 .0228108 .0296909

 dadocc | .0077382 .0013713 5.64 0.000 .0050504 .0104259

 dadunemp | -.1256167 .0477079 -2.63 0.008 -.2191225 -.0321109

 daded | .1495834 .0420635 3.56 0.000 .0671404 .2320264

 momed | .0545836 .0391762 1.39 0.164 -.0222003 .1313675

 male | -.0544371 .0288055 -1.89 0.059 -.1108948 .0020207

 deprive | -.1631975 .0262269 -6.22 0.000 -.2146014 -.1117937

 p7vrq\_sch | .0263455 .0171515 1.54 0.125 -.0072708 .0599618

 p7read\_sch | -.0199684 .0135388 -1.47 0.140 -.0465039 .0065672

 dadocc\_sch | .0248499 .0191866 1.30 0.195 -.0127552 .062455

dadunemp\_sch | 1.113901 .5183483 2.15 0.032 .0979574 2.129846

 daded\_sch | -.6698207 .447016 -1.50 0.134 -1.545956 .2063146

 momed\_sch | .4964818 .6049023 0.82 0.412 -.6891049 1.682069

 male\_sch | .3916443 .416703 0.94 0.347 -.4250787 1.208367

 \_cons | -.210726 .2503211 -0.84 0.400 -.7013464 .2798944

------------------------------------------------------------------------------

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 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.schid) | .0006947 .0015285 9.31e-06 .0518265

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neighid: Independent |

 var(dadunemp) | .0178082 .03453 .0003982 .7963269

 var(daded) | .0185407 .0282593 .0009348 .367715

 var(momed) | .0377594 .0272576 .0091741 .1554129

 var(male) | .0100372 .0143958 .0006037 .1668946

 var(\_cons) | 1.00e-14 2.19e-14 1.37e-16 7.33e-13

-----------------------------+------------------------------------------------

 var(Residual) | .4395822 .0159506 .4094055 .4719832

------------------------------------------------------------------------------

LR test vs. linear model: chi2(6) = 5.69 Prob > chi2 = 0.4594

Note: LR test is conservative and provided only for reference.

We should probably mean-center some predictors, and also examine which of them should stay (most are not significant). We could also examine some cross-level interactions, but in general, there is not that much slope variance, and very little school-level and neighborhood-level unexplained variance left.

Cross-nested models for longitudinal data

Cross-nested models can also be used with longitudinal data like NYS dataset we used earlier. Here, we can treat observations as nested both within individuals and within time points. That is, in our earlier analysis, we assumed that the trajectory of age (from 14 to 18) is linear and student-specific (a random slope). In this cross-nested model, we will assume that the effect due to specific age is systematic to that age and common to all students. The rationale behind that could be assuming that the students were measured contemporaneously, and there may have been some year-specific factors happening that affected all the students, making everyone’s deviance attitude score either higher or lower in that given year. So we will estimate a two-way crossed-nested model, with the student effects ui being crossed with the age effects vj:

. use nys.dta, clear

. reshape long attit expo, i(id) j(age)

(note: j = 14 15 16 17 18)

Data wide -> long

-----------------------------------------------------------------------------

Number of obs. 241 -> 1205

Number of variables 14 -> 7

j variable (5 values) -> age

xij variables:

 attit14 attit15 ... attit18 -> attit

 expo14 expo15 ... expo18 -> expo

-----------------------------------------------------------------------------

. mixed attit || \_all: R.age || id:

Performing EM optimization:

Performing gradient-based optimization:

Iteration 0: log likelihood = 34.695287

Iteration 1: log likelihood = 34.695287

Computing standard errors:

Mixed-effects ML regression Number of obs = 1,066

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 1,066 1,066.0 1,066

 id | 241 1 4.4 5

-------------------------------------------------------------

 Wald chi2(0) = .

Log likelihood = 34.695287 Prob > chi2 = .

------------------------------------------------------------------------------

 attit | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 \_cons | .4923777 .0267443 18.41 0.000 .4399598 .5447955

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.age) | .002475 .0016883 .00065 .0094237

-----------------------------+------------------------------------------------

id: Identity |

 var(\_cons) | .0443494 .0048906 .035729 .0550496

-----------------------------+------------------------------------------------

 var(Residual) | .0357432 .0017678 .0324411 .0393815

------------------------------------------------------------------------------

LR test vs. linear model: chi2(2) = 415.72 Prob > chi2 = 0.0000

Note: LR test is conservative and provided only for reference.

For this kind of model to make sense, we should have more time points that we do here – 5 time points is better for fixed effects of time rather than for a random variable – we do it here for demonstration purposes only. So this kind of analysis makes sense if you have a LONG time-series rather than a short one.

We can now add the trajectory, first linear non-varying, then linear randomly varying, then quadratic randomly varying:

. gen age16=age-16

. mixed attit age16 || \_all: R.age16 || id:

Mixed-effects ML regression Number of obs = 1,066

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 1,066 1,066.0 1,066

 id | 241 1 4.4 5

-------------------------------------------------------------

 Wald chi2(1) = 20.21

Log likelihood = 38.657761 Prob > chi2 = 0.0000

------------------------------------------------------------------------------

 attit | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 age16 | .0322932 .0071842 4.50 0.000 .0182124 .046374

 \_cons | .492564 .0169588 29.04 0.000 .4593255 .5258026

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.age16) | .0003369 .0003345 .0000481 .0023583

-----------------------------+------------------------------------------------

id: Identity |

 var(\_cons) | .0443475 .0048856 .0357351 .0550355

-----------------------------+------------------------------------------------

 var(Residual) | .0357263 .0017662 .0324271 .0393611

------------------------------------------------------------------------------

LR test vs. linear model: chi2(2) = 401.35 Prob > chi2 = 0.0000

Note: LR test is conservative and provided only for reference.

. mixed attit age16 || \_all: R.age16 || id: age16

Mixed-effects ML regression Number of obs = 1,066

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 1,066 1,066.0 1,066

 id | 241 1 4.4 5

-------------------------------------------------------------

 Wald chi2(1) = 15.60

Log likelihood = 60.274204 Prob > chi2 = 0.0001

------------------------------------------------------------------------------

 attit | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 age16 | .032264 .0081687 3.95 0.000 .0162537 .0482743

 \_cons | .4929646 .0172185 28.63 0.000 .4592169 .5267122

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.age16) | .0003816 .000345 .0000649 .0022449

-----------------------------+------------------------------------------------

id: Independent |

 var(age16) | .0031574 .0006363 .0021271 .0046868

 var(\_cons) | .0455911 .0048767 .0369683 .0562251

-----------------------------+------------------------------------------------

 var(Residual) | .0282275 .0016269 .0252124 .0316033

------------------------------------------------------------------------------

LR test vs. linear model: chi2(3) = 444.59 Prob > chi2 = 0.0000

Note: LR test is conservative and provided only for reference.

. mixed attit c.age16##c.age16 || \_all: R.age16 || id: c.age16##c.age16

Mixed-effects ML regression Number of obs = 1,066

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 1,066 1,066.0 1,066

 id | 241 1 4.4 5

-------------------------------------------------------------

 Wald chi2(2) = 38.20

Log likelihood = 65.811166 Prob > chi2 = 0.0000

------------------------------------------------------------------------------

 attit | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 age16 | .0319722 .0057991 5.51 0.000 .0206062 .0433381

 |

 c.age16#|

 c.age16 | -.010505 .0038782 -2.71 0.007 -.0181062 -.0029038

 |

 \_cons | .5137537 .0167022 30.76 0.000 .481018 .5464895

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.age16) | .0000505 .000123 4.25e-07 .0059915

-----------------------------+------------------------------------------------

id: Independent |

 var(age16) | .0034223 .0006344 .0023797 .0049217

 var(age16#age16) | .0005715 .0002493 .0002431 .0013437

 var(\_cons) | .0466065 .0051029 .0376053 .0577622

-----------------------------+------------------------------------------------

 var(Residual) | .0251662 .0018311 .0218214 .0290237

------------------------------------------------------------------------------

LR test vs. linear model: chi2(4) = 450.29 Prob > chi2 = 0.0000

Note: LR test is conservative and provided only for reference.

Here we note that the variance for the random effects of time points is very close to 0 – it doesn’t seem that individual time points have much of an effect beyond what’s specified by random trajectory. Let’s compare some specifications of time here:

. est store quadratic\_re

. mixed attit c.age16##c.age16 || id: c.age16##c.age16

Mixed-effects ML regression Number of obs = 1,066

Group variable: id Number of groups = 241

 Obs per group:

 min = 1

 avg = 4.4

 max = 5

 Wald chi2(2) = 46.07

Log likelihood = 65.681561 Prob > chi2 = 0.0000

------------------------------------------------------------------------------

 attit | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 age16 | .0319353 .0053468 5.97 0.000 .0214557 .0424148

 |

 c.age16#|

 c.age16 | -.0105168 .0033811 -3.11 0.002 -.0171436 -.00389

 |

 \_cons | .5137654 .0159545 32.20 0.000 .4824951 .5450357

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

id: Independent |

 var(age16) | .0034152 .000635 .0023721 .0049169

 var(age16#age16) | .0005646 .0002491 .0002378 .0013407

 var(\_cons) | .0465887 .0051017 .0375897 .057742

-----------------------------+------------------------------------------------

 var(Residual) | .0252557 .0018322 .0219083 .0291146

------------------------------------------------------------------------------

LR test vs. linear model: chi2(3) = 450.03 Prob > chi2 = 0.0000

Note: LR test is conservative and provided only for reference.

. est store quadratic

. est stats quadratic quadratic\_re

Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------

 Model | N ll(null) ll(model) df AIC BIC

-------------+---------------------------------------------------------------

 quadratic | 1,066 . 65.68156 7 -117.3631 -82.56144

quadratic\_re | 1,066 . 65.81117 8 -115.6223 -75.84898

-----------------------------------------------------------------------------

Note: BIC uses N = number of observations. See [R] BIC note.

. lrtest quadratic quadratic\_re

Likelihood-ratio test LR chi2(1) = 0.26

(Assumption: quadratic nested in quadratic\_re) Prob > chi2 = 0.6107

Note: The reported degrees of freedom assumes the null hypothesis is not on

 the boundary of the parameter space. If this is not true, then the

 reported test is conservative.

. mixed attit c.age16##c.age16 || \_all: R.age16 || id:

Mixed-effects ML regression Number of obs = 1,066

-------------------------------------------------------------

 | No. of Observations per Group

 Group Variable | Groups Minimum Average Maximum

----------------+--------------------------------------------

 \_all | 1 1,066 1,066.0 1,066

 id | 241 1 4.4 5

-------------------------------------------------------------

 Wald chi2(2) = 67.13

Log likelihood = 41.042581 Prob > chi2 = 0.0000

------------------------------------------------------------------------------

 attit | Coef. Std. Err. z P>|z| [95% Conf. Interval]

-------------+----------------------------------------------------------------

 age16 | .0322139 .0042397 7.60 0.000 .0239042 .0405236

 |

 c.age16#|

 c.age16 | -.0103426 .0034938 -2.96 0.003 -.0171903 -.0034948

 |

 \_cons | .5130924 .0163665 31.35 0.000 .4810147 .5451701

------------------------------------------------------------------------------

------------------------------------------------------------------------------

 Random-effects Parameters | Estimate Std. Err. [95% Conf. Interval]

-----------------------------+------------------------------------------------

\_all: Identity |

 var(R.age16) | 4.80e-07 .0001233 8.4e-226 2.7e+212

-----------------------------+------------------------------------------------

id: Identity |

 var(\_cons) | .044296 .0048806 .0356925 .0549734

-----------------------------+------------------------------------------------

 var(Residual) | .0357288 .0017669 .0324282 .0393653

------------------------------------------------------------------------------

LR test vs. linear model: chi2(2) = 400.75 Prob > chi2 = 0.0000

Note: LR test is conservative and provided only for reference.

. est store noslopevar

. est stats quadratic quadratic\_re noslopevar

Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------

 Model | N ll(null) ll(model) df AIC BIC

-------------+---------------------------------------------------------------

 quadratic | 1,066 . 65.68156 7 -117.3631 -82.56144

quadratic\_re | 1,066 . 65.81117 8 -115.6223 -75.84898

 noslopevar | 1,066 . 41.04258 6 -70.08516 -40.25515

-----------------------------------------------------------------------------

Note: BIC uses N = number of observations. See [R] BIC note.

The model with just the randomly varying quadratic trajectory seems to be better than either the model with the randomly varying quadratic trajectory PLUS individual time point effects, or the model with just the individual time point effects and non-varying quadratic trajectory. So we would probably set aside the idea of cross-nested model here and stick with the randomly varying quadratic trajectory model. But otherwise, we could continue adding predictors etc.