Multilevel estimation of contextual effects

Philip S. Morrison.
Victoria University of Wellington

Philip.Morrison@vuw.ac.nz

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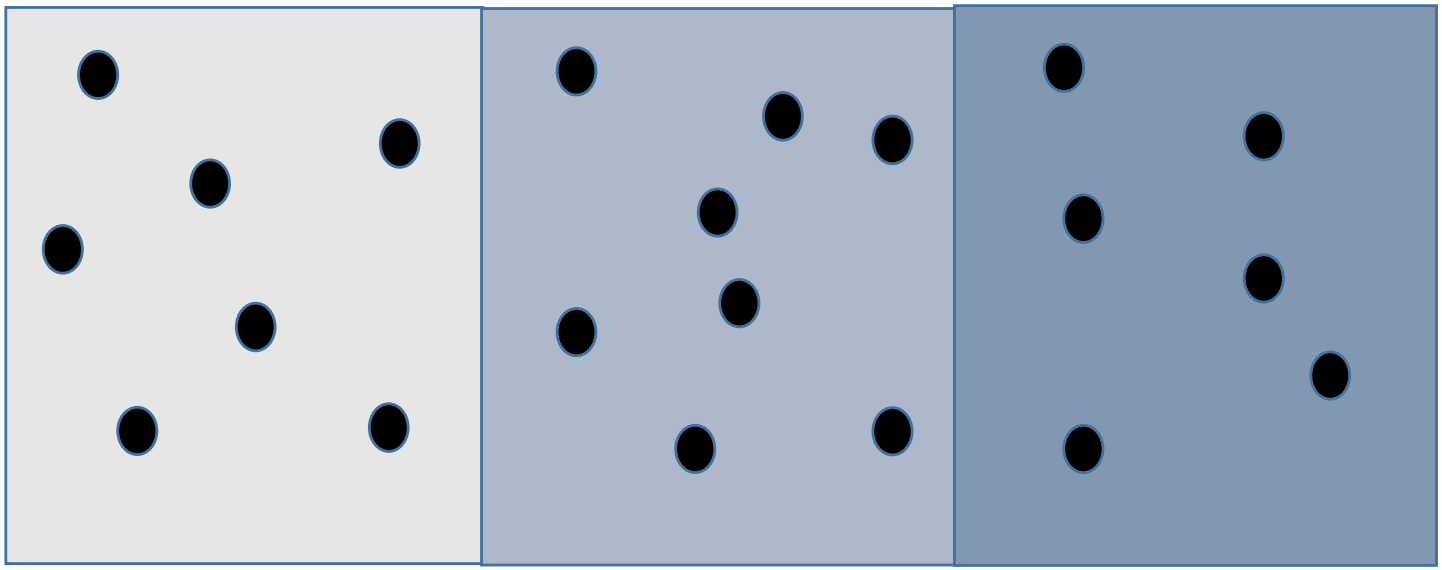
What's the problem?

The clustering of individuals ● in groups 



There are two problems: statistical and substantive

Statistical: Clustering means your sample is not made up of independent (uncorrelated) individuals. Therefore you have fewer independent observations than you think. Without adjustment your standard errors are under estimated and the chances of Type 1 errors are higher.

Substantive: Conceptually, measurements of outcomes of micro-level processes on individuals may reflect the (macro) context in which the processes operate.

Examples:

- **Education**: learning takes place in classes in schools
- **Public health**: people grow up in neighbourhoods
- **Labour economics**: workers perform within firms
- **Management**: leadership operates within organisations

Admitting the presence of multiple levels means that your theory has to be articulated at two levels:

- How individuals behave in general (at the micro level)
- How individuals behave in specific contexts (the macro level)

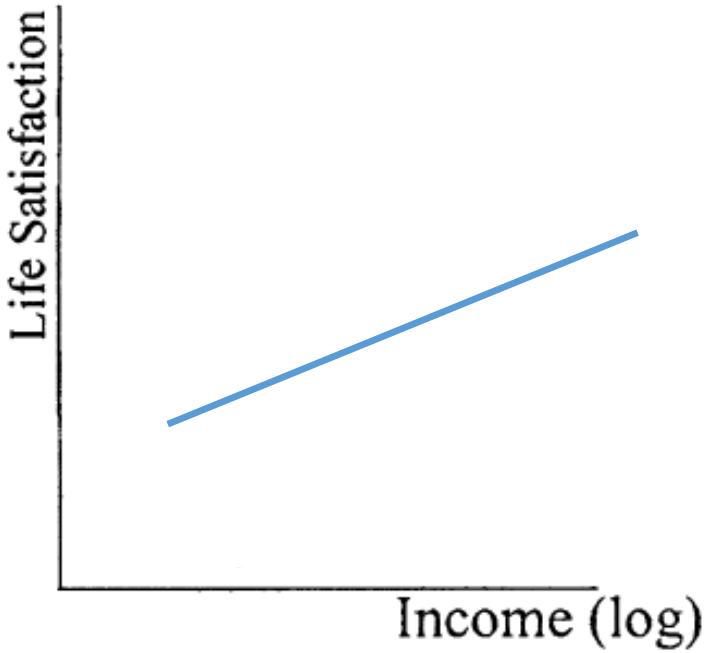
What happens if we ignore context?

Example: Schyns, Peggy. (2002) Wealth of nations, individual income and life satisfaction in 42 countries: a multilevel approach. *Social Indicators Research* 60**,** 5-40.

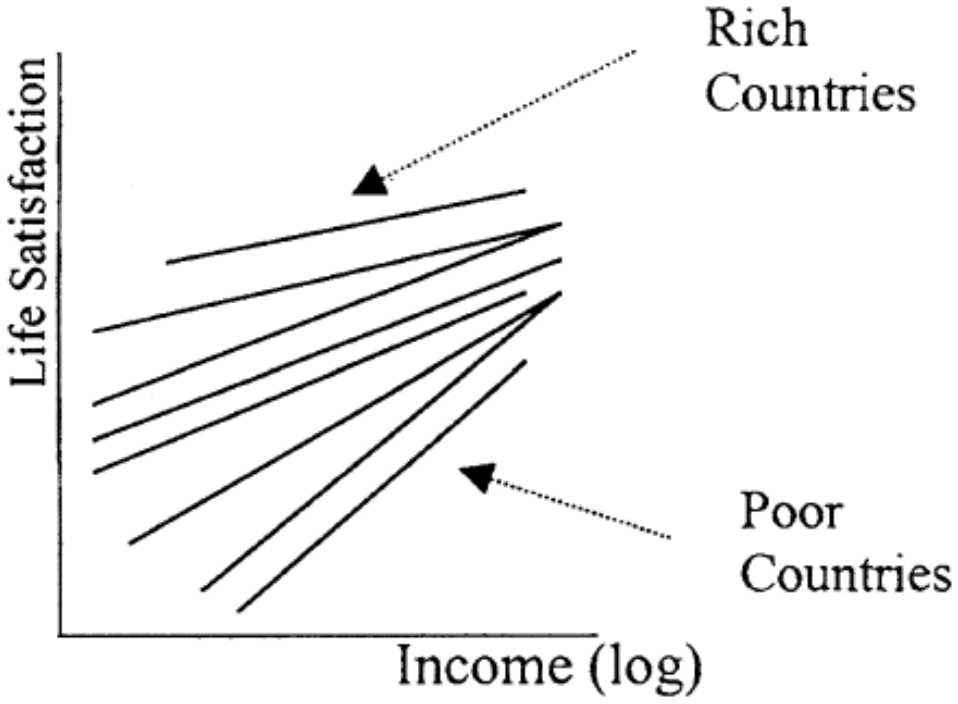
LIFE SATISFACTION = a + b INCOME(log) + e

Contexts are countries and their wealth affects both the intercept and slope.

The general (micro) relationship



Context specific relationships



The Peggy Schyns example illustrates the value of applying the multilevel model. Among other things it tells us that the wellbeing returns to raising incomes are higher in low income countries. The general, micro-level model, is not general after all.

Introductions to multilevel modelling

Bickel, R. 2007. *Multilevel analysis for applied research. Its just regression!* London: The Guilford Press.

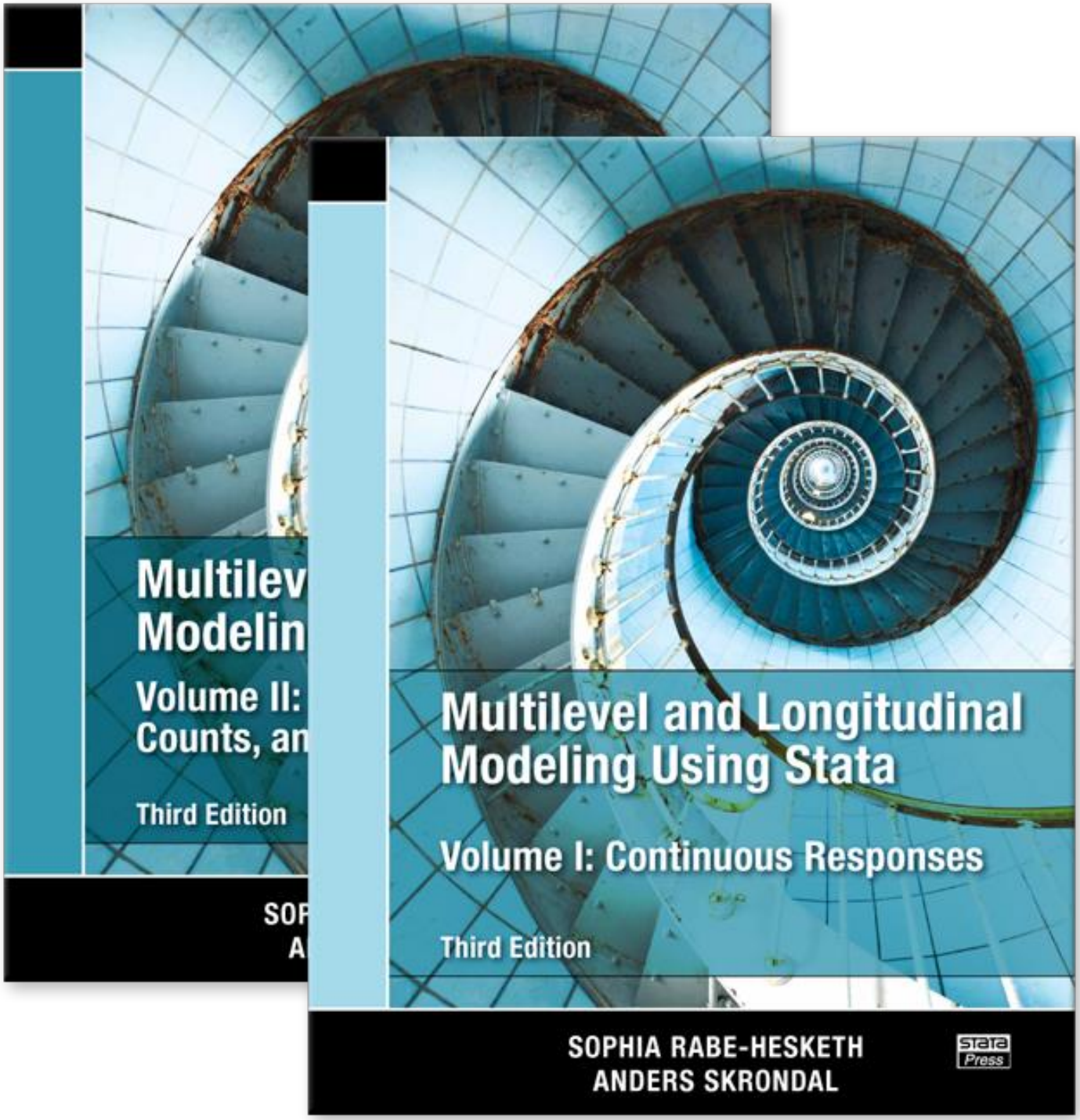
Hox, J. J. 1995. *Multilevel analysis. Techniques and applications*. New York: Routledge.

Kreft, I. & J. du Leeuw. 2006. *Introducing multilevel modelling*. London Sage Publications Ltd.

Luke, D. A. 2004. *Multilevel modelling*. London: Sage Publications.

Advanced

Rabe-Hesketh, S. & A. Skrondal. 2008. *Multilevel and longitudinal modeling using Stata*. College Station, Texas: Stata Press.


Multilev
Modelin
Volume II:
Counts, an
Third Edition
Multilevel and Longitudinal
Modeling Using Stata
Volume I: Continuous Responses
Third Edition
SOPHIA RABE-HESKETH
ANDERS SKRONDAL
stata
Press

Other basic resources

Stata manual

https://www.stata.com/manuals13/me.pdf

Huber, C. Multilevel linear models in Stata, part 1: components of variance.

Stata YouTube

http://blog.stata.com/2013/02/04/multilevel-linear-models-in-stata-part-1-components-of-variance/

Module 7: Multilevel models for binary responses. George Leckie. Centre for Multilevel modelling

http://www.bristol.ac.uk/media-library/sites/cmm/migrated/documents/7-practicals-stata-sample.pdf

ESS EduNet. European Social Survey education
Learning multilevel analysis. Prof Kristen Ringdal. Contains Stata syntax

http://essedunet.nsd.uib.no/cms/topics/multilevel/

Contemporary approaches involve specifying the general model in terms of *fixed* effects and the context as a *random* variable. Hence 'mixed' (ME = mixed estimation).

Stata offers a suite of ME routines depending mainly on the way your dependent variable is measured.

All Stata commands are in red

Mixed Mixed-effects linear regression

Mixlm Mixed-effects generalized linear regression

Melogit Mixed-effects logistic regression
Meprobit Mixed-effects probit regression

Meologit Mixed-effects ordered logistic regression
Meoprobit Mixed-effects ordered probit regression

Count, multinomial and others

Pride in the city*

Urban pride is an individual and collective response to living in a given city.

Unlike other emotions such as life satisfaction or happiness with which it is weakly positively correlated, pride involves stake holding; to be proud of something requires having an investment in its success either emotionally, financially, culturally or as a participant.

I specify a multilevel model based on responses to a five category survey question on how proud residents are in the 'look and feel of their city' drawing on over 6000 residents surveyed in 12 New Zealand cities in 2008.

* Adapted from Morrison, Philip.S. 2016 'Pride in the city' REGIONS (in press as of 19 Oct 2016) http://region.wu.ac.at/

Survey question:

Q: “On a scale of one to five where one is strongly disagree and five is strongly agree, rate your agreement with the statement “*I feel a sense of pride in the way [my city] looks and feels.*”

Responses to the statement “I feel a sense of pride in the way [my city] looks and feels”. Twelve New Zealand cities, 2008.

Response	Frequency	Percent	Cumulative percent
Strongly disagree	82	1.34	1.34
Disagree	389	6.36	7.7
Neutral	1,803	29.48	37.18
Agree	2,763	45.17	82.34
Strongly agree	1,080	17.66	100
Total	**6,117**	100	

Source: Quality of Life Survey, 2008.
Note: Excludes 21 respondents who did not know.

The location of the twelve cities included in the Quality of Life project. New Zealand, 2008

1. Rodney
2. North Shore
3. Waitakere
4. Auckland
5. Manukau.
6. Hamilton
7. Tauranga.
8. Porirua
9. Hutt
10. Wellington
11. Christchurch
12. Dunedin

Beginning with the OLS model

Most studies of responses apply the conventional OLS 'total' regression model specified at the level of the i^{th} individual in which the relationship between the outcome y and arguments X are described in terms of *fixed* parameters, α and β.

$$(1) \qquad \boldsymbol{y}_i = \alpha_o + \beta X_i + \boldsymbol{\varepsilon}_i$$

In such a model the random or allowed-to-vary element is captured by ε, the mean or expected value of which is assumed to be zero.

An accompanying assumption is that there is constant variability and no autocorrelation. The assumption is necessary if it is to be characterised by a single parameter σ^2_ε, the variance of the error term.

For illustration of the general relationship, lets assume that pride in the city can be 'explained' by the age of the resident:

y = pride* and x = age.

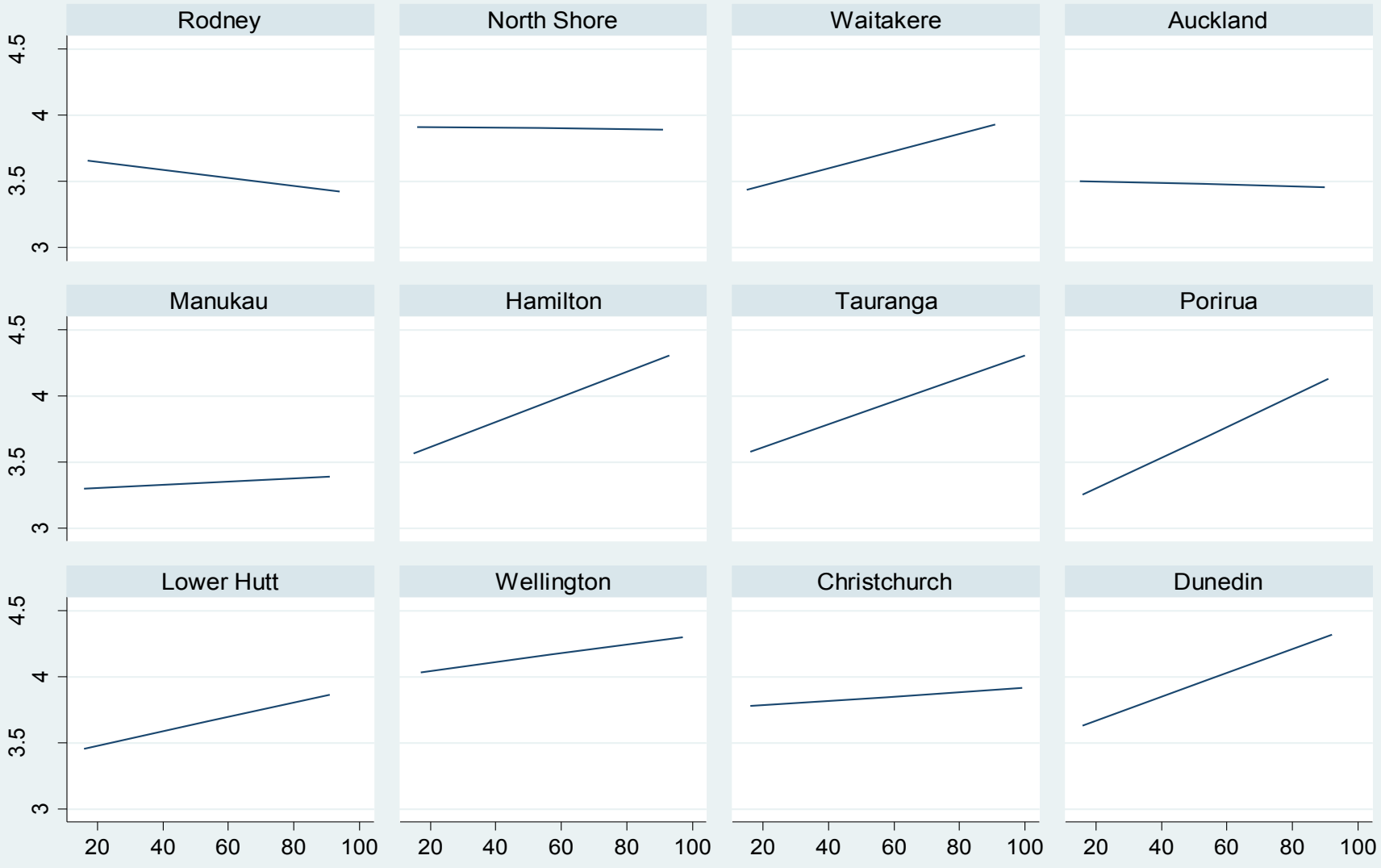
```
regress pride age
```

```
      Source |       SS           df       MS      Number of obs   =     6,117
-------------+----------------------------------   F(1, 6115)      =     50.10
       Model |  38.0129991         1  38.0129991   Prob > F        =    0.0000
    Residual |  4640.04814     6,115  .758797734   R-squared       =    0.0081
-------------+----------------------------------   Adj R-squared   =    0.0080
       Total |  4678.06114     6,116  .764889003   Root MSE        =    .87109

------------------------------------------------------------------------------
      pride |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------+-----------------------------------------------------------------
        age |   .0044873    .000634     7.08   0.000     .0032445    .0057302
      _cons |   3.515622   .0302126   116.36   0.000     3.456395    3.574849
------------------------------------------------------------------------------
```

Does this *general* (micro-level) relationship apply to all cities?

* I treat the ordinal dependent variable as cardinal for ease of interpretation. See Ferrer-i-Carbonell, A. & P. Frijters (2004) How important is methodology for the estimates of the determinants of happiness? *The Economic Journal,* 114**,** 641-659 and Kristoffersen, I. (2010) The metrics of subjective wellbeing: cardinal neutrality and additivity. *The Economic Record,* 86**,** 98-123

Differences in the linear OLS relationship between urban pride and age across the 12 cities. New Zealand 2008.



The two parameters of the model both vary by city. Lets begin by assuming only intercepts vary.

The random intercepts model

Assume cities are sampled and treat the intercept as a random variable

$$(1) \qquad \boldsymbol{y}_i = \alpha_o + \beta X_i + \boldsymbol{\varepsilon}_i$$

$$(2) \qquad \boldsymbol{y}_i = \alpha_{oj} + \beta X_i + \boldsymbol{\varepsilon}_{ij}$$

We now have two subscripts, i = individual and j = city.

α_{oj} Indicates variability in the intercept from city to city, the 'city effect'. We treat this as a 'random effect' and represent it as a variance.

$\boldsymbol{\varepsilon}_{ij}$ Indicates presence of a second level variability….

Average levels of urban pride are allowed to vary from city to city. The average level of urban pride in city j is the sum of the city-wide average, α_o, and a varying difference $\boldsymbol{u}_j$.

The aim of the model is to estimate the fixed intercept, α_o, representing the average level of urban pride across the country, and the variance, σ^2_{μ}, which measures its inter-city variability about this average.

(2) $$a_{oj} = \alpha_o + \boldsymbol{u}_j$$

Combining the micro equation (above) and the macro equation of (2) produces the two-level mixed model in (3):

(3) $$\boldsymbol{y}_{ij} = \alpha_o + \beta x_{ij} + (\boldsymbol{u}_j + \boldsymbol{\varepsilon}_{ij})$$

The terms in bold denote the random part.

The initial step in applying the random coefficients model is to estimate the proportion of the variance attributable to differences among individuals and cities. In this null model.

(4) $$y_{ij} = \alpha_o + (\boldsymbol{u}_j + \boldsymbol{\varepsilon}_{ij}),$$

the proportion of the variance attributable to individuals is

$\sigma^2_\varepsilon /(\sigma^2_\varepsilon + \sigma^2_\mu)$

and the variation across cities

$\sigma^2_\mu /(\sigma^2_\varepsilon + \sigma^2_\mu)$

the *intra-class correlation* ρ(rho).

The intra-class correlation is a measure of the degree to which individuals share common experiences due to their residence in the same city.

If ρ is greater than zero then there is a case for applying a random coefficients model and its extension as a multilevel model.

The null model Random terms only, City `mixed pride || City:`


```
Mixed-effects ML regression                     Number of obs     =      6,117
Group variable: City                            Number of groups  =         12

                                                Obs per group:
                                                              min =        497
                                                              avg =      509.8
                                                              max =        535

Log likelihood = -7698.2485                     Wald chi2(0)      =          .
                                                Prob > chi2       =          .
------------------------------------------------------------------------------
       pride |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   3.716021   .0612555    60.66   0.000     3.595963     3.83608
------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects Parameters  |   Estimate   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
City: Identity               |
                  var(_cons) |  .0436127   .0183748      .019098    .0995954
-----------------------------+------------------------------------------------
               var(Residual) |  .7206042   .0130427      .695489    .7466263
------------------------------------------------------------------------------
LR test vs. linear model: chibar2(01) = 322.29        Prob >= chibar2 = 0.0000
```

α

μj

εij

```
estat icc    // Estimates intraclass correlations. Default is 95% conf. interval

Intraclass correlation

------------------------------------------------------------------------------
                       Level |        ICC   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
                        City |   .0570685    .022694      .0257981    .1215147
------------------------------------------------------------------------------
```

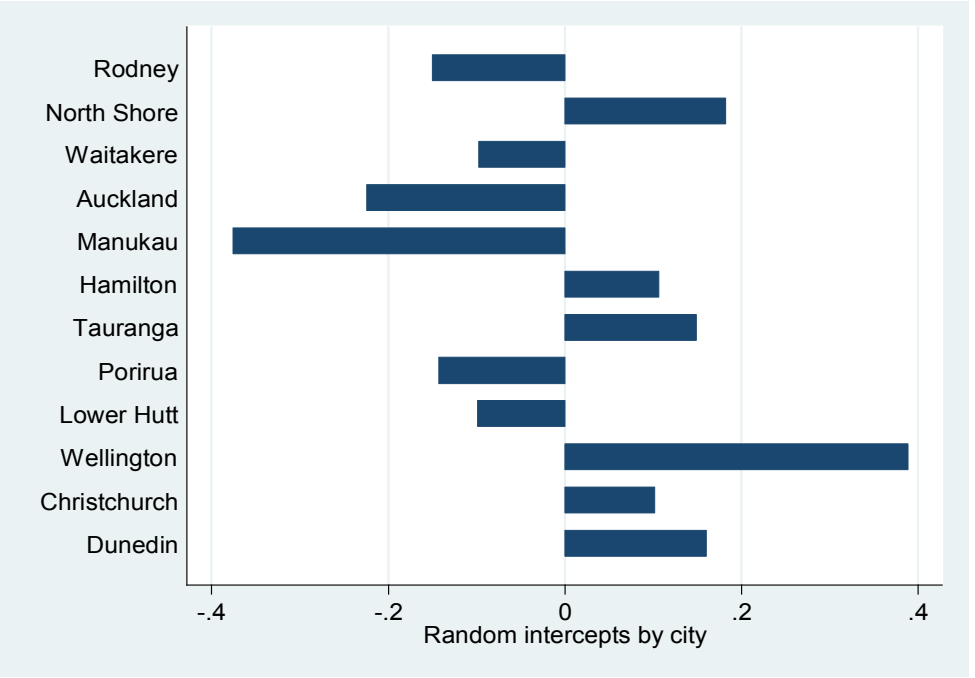
```
display 4.36/(4.36+72.06)
.057
```

```
estat ic     // Gives ll(model), df, AIC and BIC

Akaike's information criterion and Bayesian information criterion

------------------------------------------------------------------------------
       Model |        Obs  ll(null)  ll(model)      df         AIC        BIC
-------------+----------------------------------------------------------------
           . |      6,117          .  -7698.248       3     15402.5   15422.65
------------------------------------------------------------------------------
               Note: N=Obs used in calculating BIC; see [R] BIC note.
```

The random intercepts model

The random intercept model of equation 4 implies a different intercept term for each city, $\alpha + \mu_j$; $j = 1,\ldots,12$. These random intercepts are not estimated directly but we can use linear unbiased predictions (BLUPS) of their random effects as shown on the right. Recall that the mean level of pride is 3.71 on the urban pride 1-5 scale with a standard deviation of 0.874. At one extreme the City of Manukau has a half standard deviation measure lower than the grand mean, and Wellington City almost 0.4 higher.

Urban pride: predicted random intercepts by city. New Zealand 2008.



Source: Quality of Life Survey, 2008.

‘Table 1’. Describing the arguments

Measures of stake holding and controls used in the modelling of urban pride. New Zealand, 2008

Variable	Description	Mean	Std Dev
Controls			
Female	Female	0.53	0.50
Health	Health good or very good	0.61	0.49
Emotional stakes			
Duration	Resident in city 10 years +	0.70	0.46
Community	Sense of community	0.55	0.50
Financial stakes			
Owner	Home owner	0.62	0.49
Not employed	Not employed	0.26	0.44
Enough	Income meets everyday needs	0.87	0.34
Cultural stake			
Minority	Non-European	0.23	0.42
Civic stakes			
Safe	Feel safe in central city	0.63	0.48
Clean	No rubbish noticed	0.49	0.50
Council	Confidence in council decisions	0.46	0.50

Source: Quality of Life Survey, 2008.

The distribution of urban pride. Stake holding fixed effects and city random effects. New Zealand, 2008

Variable	Description	Coef.	Std Err.	z	P>|z|
FIXED EFFECTS					
Controls					
Female	Female	0.10	0.02	4.91	0.00
Health	Health good or very good	0.06	0.21	3.01	0.00
Emotional stakes					
Duration	Resident in city 10 years +	0.11	0.02	4.78	0.00
Community	Sense of community	0.24	0.02	11.22	0.00
Financial stakes					
Owner	Home owner	0.08	0.22	3.80	0.00
Not employed	Not employed	0.06	0.02	2.45	0.01
Enough	Income meets everyday needs	0.10	0.03	3.17	0.00
Cultural stakes					
Minority	Non-European	0.20	0.03	7.44	0.00
Civic stakes					
Safe	Feel safe in central city	0.21	0.02	9.37	0.00
Clean	No rubbish noticed	0.23	0.02	11.20	0.00
Council	Confidence in council decisions	0.37	0.02	17.68	0.00
Constant		2.80	0.07	37.36	0.00
RANDOM EFFECTS					
		Estimate	**Std Err.**		
Cities	Constant	0.04	0.02		
	Residual	0.61	0.01		
Number of cases	5867				
Log likelihood	-6897.12				
LR test vs linear model:	348.72				
Wald chi2 pr=0	982.88				
Df	14				
AIC	13822.23				
Intraclass correlation	0.07				

Source: Quality of Life Survey, 2008

Selected characteristics of the twelve New Zealand cities

City	Pride	Population ('000)	Affluence	European	Council
Rodney District	3.56	89.56	0.10	0.95	0.30
North Shore City	3.90	205.61	0.13	0.77	0.44
Waitakere City	3.62	186.44	0.07	0.67	0.48
Auckland City	3.48	404.66	0.14	0.62	0.40
Manukau City	3.33	328.97	0.07	0.46	0.51
Hamilton City	3.83	129.25	0.07	0.76	0.57
Tauranga City	3.87	103.64	0.06	0.88	0.40
Porirua City	3.57	48.55	0.10	0.66	0.51
Lower Hutt City	3.61	86.93	0.09	0.75	0.47
Wellington City	4.12	179.47	0.17	0.81	0.50
Christchurch City	3.82	348.44	0.07	0.88	0.41
Dunedin City	3.88	118.68	0.05	0.92	0.46

Source: Census of Population and Dwellings, 2006 *and* Quality of Life Survey, 2008

Population is drawn from the nearest population census (2006). **Affluence** is the proportion of individuals with pre-tax incomes of over $70,000 per annum. **European** is the proportion of European in the city. **Council** is the proportion of the city population who agree or strongly agree that the council makes decisions that are in the best interest of their city (aggregated from sample responses).

The multilevel model

In the urban pride case cities are contexts and as such their characteristics may influence the way the micro level arguments raise or lower urban pride.

I test three hypotheses:

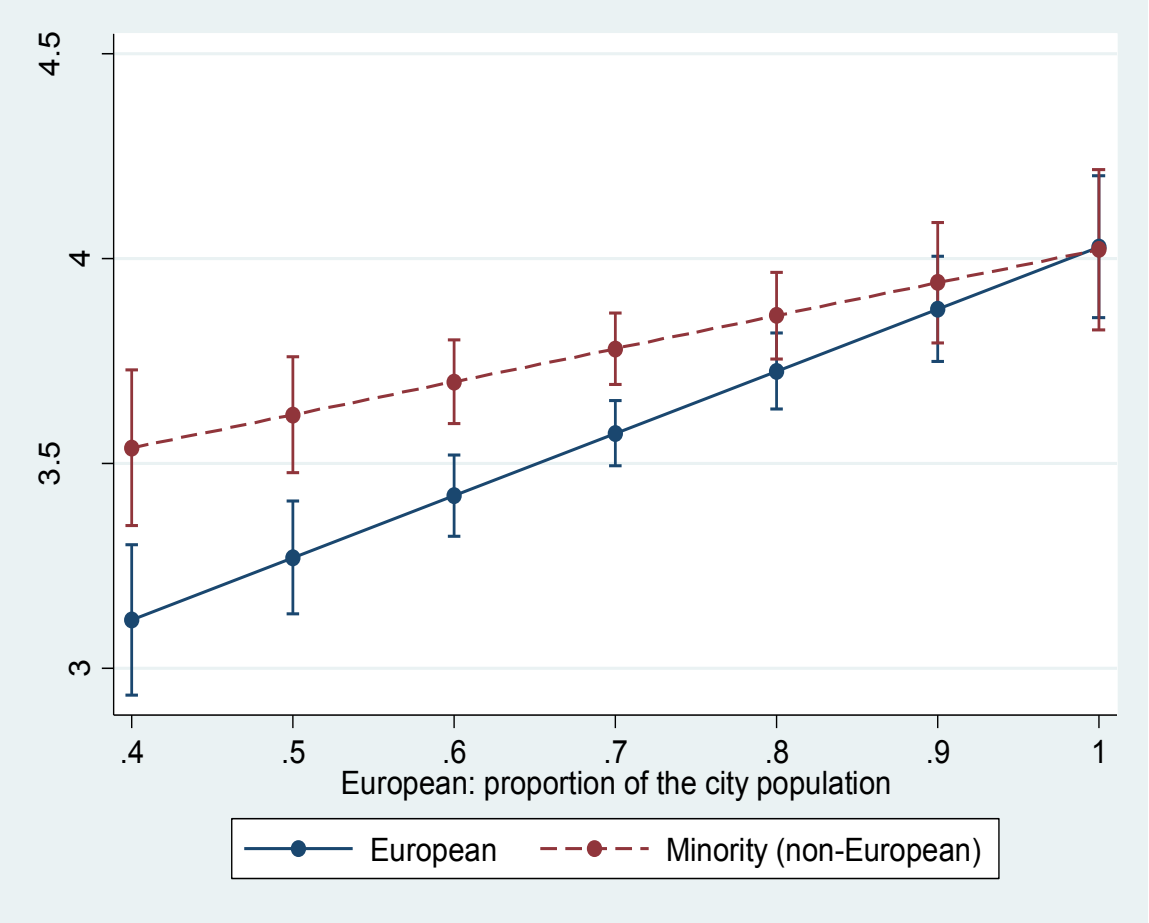
1. whether the higher levels of urban pride exhibited by minorities rise as their share of the population increases,

```
mixed pride female healthGVG duration community_sense owner not_employed
enough i.minority  safeCC no_rubbish conf_council ///
i.minority##c.EuropeanPr ///
|| City:  EuropeanPr , mle
```

2. whether not having enough money lowers urban pride to a greater extent more affluent cities, and

3. whether the individuals' support for council rises in cities where the overall support for council is higher and whether this contexteffect is greater for owners.

How the impact of minority status urban pride falls as the proportion of European in the city rises. New Zealand, 2008



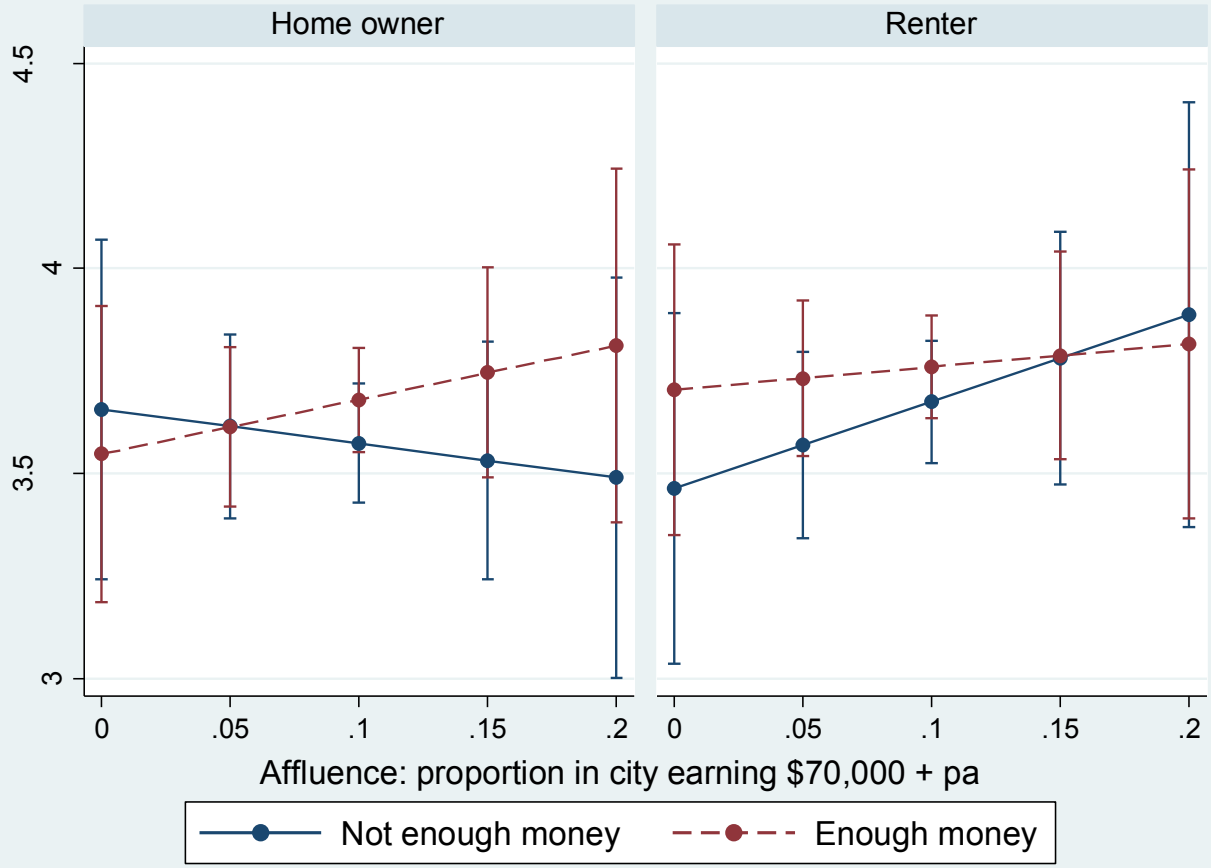
Source: Quality of Life Survey, 2008 and Census of Population and Dwellings, 2006.
Note: With the fixed effects in the model, the addition of the cross-level term (minority x European) is β = -0.710 (SE=0.19; z= -3.74).

The *a priori* argument is that minorities will return higher levels of pride in cities where they make up a larger share of the population. The greater their proportion the greater the sense of identity and collective strength.

The focus in this case therefore is on the interaction of the level 2 variable 'European' and the individual or level 1 variable 'minority'.

In the fixed effects results above, minorities return higher levels of urban pride than the European majority. Applying the interaction term exposes the fact that urban pride rises with the proportion of European. This rise is much slower in the case of minorities, and, as the dashed line shows, urban pride levels of minority and European converge as the European share grows. Context in this case clearly matters.

The effect of 'not having enough money' on urban pride by city affluence by housing tenure. New Zealand, 2008



Source: Quality of Life Survey, 2008 and Census of Population and Dwellings, 2006.

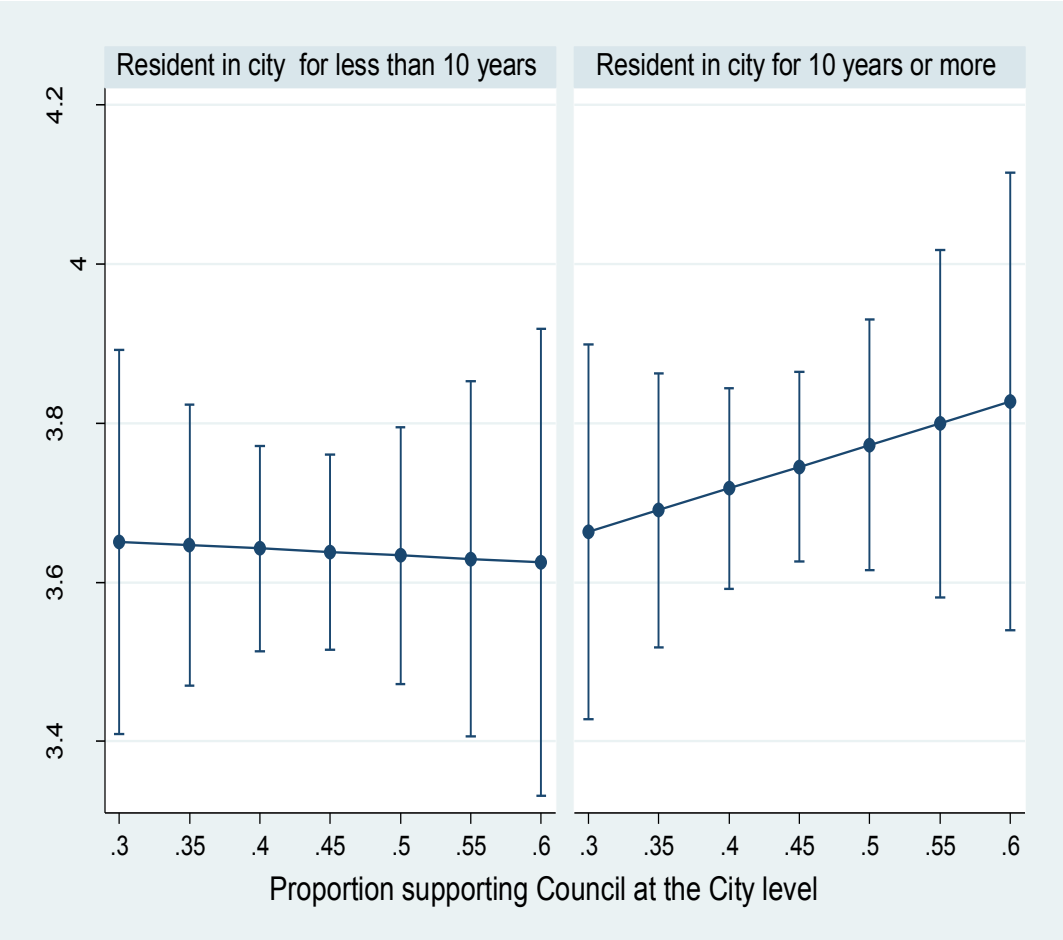
Note: With the same fixed and random effects as aboveadding the interaction of enough x owner x affluence term yields a coefficient of -3.72 and a standard error of 1.91 and a z of -1.95 and p>(z) of 0.052. The 95% confidence intervals are plotted.

When having enough money is interacted with city affluence separately for owners and renters renters without enough money (typically younger residents) return higher levels of urban pride in more affluent cities: the solid line, right panel.

By contrast, owners without enough money (typically older residents), return lower levels of urban pride in more affluent cities (solid line, left panel).

Renters and owners who say they have enough money to meet daily needs return more urban pride in more affluent cities (the dashed lines). However, city affluence has a greater effect on the urban pride of homeowners (dashed line, left panel).

The estimated relationship between urban pride and city wide support for Council among longer and shorter term residents. New Zealand, 2008



Source: Quality of Life Survey, 2008.
Note: The estimate of the Council x duration interaction term is β = 0.631 (se= 0.32), z = 1.97.

Those who see city councils acting in the interests of the majority return higher levels of urban pride. However this relationship may be affected by how long people have lived in the city.

The interaction of duration of residence (level 1) with support for Council (level 2) , suggests that the positive relationship between urban pride and the city's confidence in its council only applies to the longer term residents. The pride experienced by relative newcomers in their city appears unaffected by the confidence the city as a whole has for its council. The 95% confidence intervals are relatively wide in this case but with the fixed effects in the model the interaction between duration and Council is statistically significant.

Summary

1. In the social sciences, *context* usually matters – statistically and substantively
2. Stata's ME commands off most options non-specialist users will need.
3. Running the null model can act as a quick test for clustering
4. The urban pride example above illustrates the role of fixed effects (stake holding in this case) in the micro or level 1 model as well as how the characteristics of the context (the city) interact with level 1 arguments to alter patterns of urban pride.
5. Conceptualising multilevel models invites researchers to be more specific about the theory behind both the micro (level 1) model and the macro (level 2) model *and* the cross-level interactions.
6. At the end of the day it may be the way the multilevel model forces us to think about the theoretical role of context which is its greatest value.