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Methods in Political Science
13 April 2026

Paneldata

Inference, identification and dynamics

Introduction

Examples of panel data

- The country-year dataset from QoG.
- Election periods in Swedish municipalities.
- A survey where each individual participates multiple times.

Introduction

The structure of today's lecture

- Introduction to paneldata
- Inferential challenges (correct standard errors)
- Identification (which variation we want to use)
- Dynamics (the effect's time-profile)
- Model selection.

We will repeat some things from earlier lectures from the perspective of paneldata (e.g., fixed effects, clustering).

Introduction

Literature

- Beck & Katz 1995 as illustration of inferential problems and methodological debate. We use clustering instead of PCSE.
- Wilson & Butler 2007 as illustration of the problem of reading a suggested technique as a template, the importance of fixed effects, and methodological debate.
- Beck & Katz 2011 as a guide on modeling dynamics.
- Nyman 2026 as my take on the key takeaways.

The lecture follows my text closely.

Introduction

Some terminology

- Cross-sectional (several units at a single point in time)
- Time series (single unit over time)
- Panel data (several units over time)
 - Time-Series Cross-Sectional (long time dimension)
 - Longitudinal (short time dimension)
- Repeated cross-section (units differ across time)

The panel data terminology is not universally shared.

Introduction

Some notation

- Two dimensions – space (or panel/unit) and time.
- We use subscripts to describe at what level/dimension a variable or coefficient varies.

$$y_{i,t} = a + b_1 x_{i,t} + b_2 z_i + e_{i,t} \quad (1)$$

Feel free to replace letters as you like.

Inferential challenges

Correlated residuals

- Conventional standard errors are biased if residuals are correlated.
- With panel data, that is usually the case.
 - Serial correlation (e.g., $e_{i,t}$ and $e_{i,t-1}$)
 - Spatial correlation (e.g., $e_{i,t}$ and $e_{j,t}$)
- Usually, this makes us underestimate the statistical uncertainty.

Inferential challenges

Clustering the residuals

- There are many ways to adjust the standard errors, but clustering has established itself as the de facto standard.
- No universally best, but no need to learn anything else.
- Clustering rests on a clear assumption: residuals may be correlated within clusters, but are independent between them.

Inferential challenges

Clustering the residuals

- If you suspect both serial and spatial correlation, you can cluster on both unit and time (two-way clustering).
- Avoid having too few clusters (>40 is unproblematic).
- There can be multiple reasonable clustering choices, and there is not always a single right answer.
- Do not choose the standard errors which let you keep your significance stars.

Inferential challenges

Example

- Let us assume we are interested in how government ideology affects taxation.
- Independent variable: binary indicator for right-wing government (based on `cpds_govlr`).
- Dependent variable: tax revenues as percent of GDP (`ictd_taxinsc`).

Look at how clustering affects the standard errors.

Inferential challenges

	(1)	(2)
Right _t	-2.176*** (0.427)	-2.176 (1.372)
Constant	35.148*** (0.361)	35.148*** (1.547)
Country FE	No	No
Year FE	No	No
Observations	1156	1156
Adj. R-sq	0.021	0.021

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Controlling for space and time

- We have discussed fixed effects before, but they have a certain status in panel data analyses.
- Unit fixed effects control away the between-variation and keep the within-variation. With panel data, within equals temporal variation.
- That means controlling for all time-invariant confounders and only using the deviations from the unit average.
- I.e., within the same unit, are years when x is higher than usual also years when y is higher or lower than usual?
- In the context of panel data, a ‘fixed effect model/estimator’ refers to unit fixed effects.

Controlling for space and time

Fixed effects involve trade-offs

- 'Controlling for' sounds good, but means that you put more weight on other variation. Is that less susceptible to bias?
- Time fixed effects control for all time-specific confounders.
- Two-way fixed effects mean both unit- and time fixed effects.
- The remaining variation is unit-differences in how the variables change over time.

Yet it remains the standard for panel data.

Controlling for space and time

First differences

- Another way to remove time-invariant unit-specific confounders is to analyze *changes* rather than *levels*.
- We subtract the previous observation from the current one ($\Delta x_{i,t} = x_{i,t} - x_{i,t-1}$) and estimate:

$$\Delta y_{i,t} = a + b\Delta x_{i,t} + \Delta e_{i,t} \quad (2)$$

Controlling for space and time

Compared to fixed effects

- Like unit fixed effects, first differences remove all time-invariant confounders.
- OVB if confounders affect the trend in x and y .
- In a first-difference model, adding unit fixed effects absorbs unit-specific linear trends.
- With only two time periods ($T = 2$), first differences and fixed effects are equivalent.
- With more than two periods, they are similar but not identical:
 - Fixed effects use deviations from the unit mean.
 - First differences use period-to-period change and are therefore more sensitive to precise timing of effects.

Controlling for space and time

FE/Levels or changes?

- Can you assume that a change in x is associated with a change in y in a particular year, or just that periods with certain values on x are associated with certain values on y ? Consider both theory and measurement errors.
- Think about possible confounders in the same way. Is the risk for OVB smaller under more strict timing assumptions?
- It is common but not necessary to have both x and y as either levels or changes.
 - Sometimes a variable is already a change measure (e.g., inflation, growth).
 - Sometimes levels are associated with changes.

FE is much more common than first-differences.

Controlling for space and time

Random effects

- Random effects are an alternative to unit fixed effects and can be seen as a middle ground between pooled OLS and FE.
- Like pooled OLS, RE assumes that the independent variables are uncorrelated with the unit effects. Otherwise biased, though often less so than pooled OLS.
- RE can be more efficient (more precise) than pooled OLS if observations are correlated within units because it gives less weight to observations with overlapping information.
- I rarely encounter random effects in applied work.

Controlling for space and time

The Hausman test

- A common procedure is to let a Hausman test choose between fixed and random effects.
- It tests whether the two estimators are different enough to rule out that they are both unbiased (consistent).
- But there are problems letting a test decide:
 - Not rejecting the null does not mean that the difference is zero. There was just insufficient power to say for sure.
 - A biased estimator may be preferred to an unbiased if the former provides much better precision. The Hausman test does not evaluate this trade-off.
 - The FE estimator may be biased and a difference vs RE is not necessarily to the benefit of fixed effects.

Controlling for space and time

	(1)	(2)	(3)	(4)
Right_t	-2.176 (1.372)	-0.109 (0.386)	-0.115 (0.319)	
ΔRight_t				0.050 (0.247)
Constant	35.148*** (1.547)	33.668*** (0.276)	33.673*** (0.228)	0.078** (0.0316)
Outcome	Levels	Levels	Levels	Change
Country FE	No	Yes	Yes	No
Year FE	No	No	Yes	No
Observations	1156	1156	1156	1046
Adj. R-sq	0.021	-0.001	0.841	-0.001

Standard errors in parentheses, clustered at country. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Dynamics

The standard model assumes immediate responses and no persistence.

$$y_{i,t} = a + b_1 x_{i,t} + e_{i,t} \quad (3)$$

- If x increases by 1, y immediately increases by b .
- What happened at $t - 1$ has no effect on $y_{i,t}$.

Dynamics

Some common violations

- Counter-acting forces and movement toward a new equilibrium
 - If the right always governs, will taxes fall forever? No — the existing tax level also matters.
- Persistence and incrementalism
 - Budgets are a classic example.
- Lagged effects
 - Policies may take time to implement, and behavior may take time to adjust.

Dynamics

Three key models

- The Finite Distributed Lag (FDL) model has lags of x .
- The Lagged Dependent Variable (LDV) model has a lag of y .
- The Autoregressive Distributed Lag (ADL) model has both.

These *terms* are not important. Focus on understanding lags.

Lag = measured at an earlier point in time, typically $t - 1$.

The Finite Distributed Lag (FDL) model

$$y_t = a + b_1x_t + b_2x_{t-1} + e_t \quad (4)$$

- We can add more lags, both of x and of other variables.
- x has an immediate effect (b_1) and a one-period lagged effect (b_2).
- The effect of a temporary change in x is short-lived: with one lag, it has disappeared by $t + 2$.
- The long-run effect of a permanent change in x is $b_1 + b_2$.

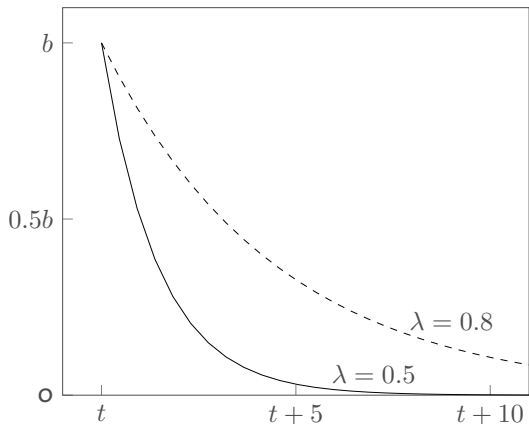
The Lagged Dependent Variable (LDV) model

$$y_t = a + \lambda y_{t-1} + bx_t + e_t \quad (5)$$

- The model allows for an incremental or slow-moving system.
- λ should be between 0 and 1. The closer it is to 1, the more persistent the outcome.
- The immediate effect of x is b .
- The long-run effect of a permanent change in x is $\frac{b}{1 - \lambda}$.

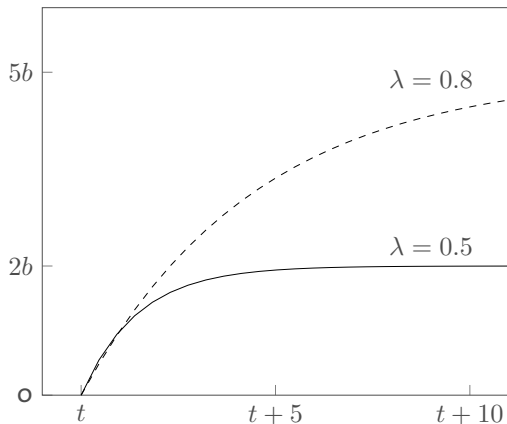
Dynamics

Change in $\hat{y}$ from a temporary change in x



Dynamics

Change in $\hat{y}$ from a permanent change in x



Nickell bias

- In short panels, LDV models with unit fixed effects are biased.
- The bias shrinks as T grows, so it is mainly a problem when the time dimension is short.
- We will not cover the causes or possible solutions in this course.

The Autoregressive Distributed Lag (ADL) model

$$y_t = a + \lambda y_{t-1} + b_1 x_t + b_2 x_{t-1} + e_t \quad (6)$$

- Combines a lag of the dependent variable with lags of the independent variable.
- The FDL model is the special case where $\lambda = 0$.
- The LDV model is the special case where $b_2 = 0$.
- The long-run effect of a permanent change in x is $\frac{b_1 + b_2}{1 - \lambda}$.

Dynamics

Empirical application

- Coefficients are not always directly comparable across models.
- Depending on the model we can now estimate different kinds of implied dynamics:
 - The immediate effect,
 - The effect after one period,
 - The long-run effect,
 - The speed of adjustment.

Dynamics

	(1)	(2)	(3)	(4)
Right_t	-0.109 (0.386)		0.308 (0.392)	
Right_{t-1}		-0.140 (0.378)	-0.466* (0.270)	-0.035 (0.089)
$\text{Tax revenues}_{t-1}$				0.973*** (0.007)
Constant	33.670*** (0.276)	33.670*** (0.270)	33.500*** (0.310)	1.010*** (0.285)
Country FE	Yes	Yes	Yes	No
Year FE	No	No	No	No
Observations	1156	1151	1071	1125
Adj. R-sq	-0.001	-0.000	-0.000	0.963

Standard errors in parentheses, clustered at country. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Model choice

A large number of choices

- What variation do you want to use?
 - All variation (OLS/RE)
 - Within-variation (FE)
 - Within-variation net of common time shocks (TWFE)
 - Period-to-period changes (FD)
- How do the dynamics work?
 - The outcome is persistent/self-reinforcing (LDV).
 - It takes a time unit or two before the full effect kicks in (FDL)
- How should you cluster the residuals?

Model choice

Three perspectives on model choice

- Let theory and substantive intuition guide the model.
 - The model should be a simplified but plausible representation of the data-generating process.
 - This is what I emphasize most.
- Use a standard specification that is common in your field.
 - Beck and Katz (2011) provide an example of this approach.
- Start with a general model. Remove irrelevant parameters.
 - Simpler models can often be understood as restricted versions (some $b = 0$) of more general ones.
 - De Boef and Keele (2008) emphasize this strategy.

Three compatible perspectives rather than distinct approaches?

Model choice

Empirical application: Lagging the independent variable?

- Budgets are typically passed during the fall which precedes the fiscal year, which could motivate lagging the right-wing indicator.
- But government changes already appear one year after the election for countries with fall elections (variable is coded based on share of the year in office).
- Best solution: recode the variable based on source data to identify the incumbent when the budget was passed.

Model choice

Empirical application: Levels or changes?

- Tax revenues change incrementally, so we should either look at changes or include a lagged outcome. With λ close to 1 they are rather similar.
- I assume a government will keep adjusting policy towards its (distant) preferred value also after its first year in office. Therefore I want the independent variable in levels.

Model choice

Empirical application: Other things

- Fixed effects are perhaps not necessary as we have already removed most of the time-invariant variation. But I think I would still include them.
- Year fixed effects may be just as relevant.
- Country-clustered standard errors are a must.

Remember the three perspectives. Others may approach this differently.

Model choice

Still a bunch of possible models

- There are often several reasonable models to choose from.
- Results may differ, and sometimes they are not directly comparable.
- No single specification will convince every sceptic.

Next week we turn to a less model-dependent approach.