Large-N statistical (econometric) analyses in environmental economics

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SESYNC
Annapolis, MD
November 2, 2015

What is econometrics?

- Application of statistical methods to economic questions.
- Links to methods of empirical analysis in many other social sciences (political science, sociology, …) some medical sciences (epidemiology), some natural/physical sciences (ecology).
  - Fields that value and sometimes perform experiments, but are often stuck with using observational data to evaluate hypotheses of interest.

"Taking the 'con' out of econometrics"

- "Credibility revolution" in empirical economics since ~1990s – strong focus on causality and identification.

- The modern econometrics ("program evaluation") toolkit:
  - Randomized experiments
  - Regression models with flexible controls for potential confounders – those variables that might mask causal effects of interest
  - Instrumental variables models for the analysis of real and natural experiments
  - Differences-in-differences type strategies that use repeated observations to control for unobserved omitted factors

Angrist, JD, and J-S Pischke. The credibility revolution in empirical economics: how better research design is taking the con out of econometrics. *J. Econ. Perspect*. 24(2): 3-30.

Angrist & Pischke's four questions

- (1) What is the causal relationship of interest?
  - How does an ESA listing affect the survival probability of a species?
  - How does information disclosure affect drinking water violations?
  - Do protected areas reduce tropical deforestation?
  - What is the effect of air pollution regulations on mortality?
  - Does "spring protection" reduce the incidence of waterborne disease?

- (2) What is the (real or hypothetical) experiment that could ideally be used to capture the causal effect of interest?

Angrist, JD, and J-S Pischke. *Mostly Harmless Econometrics*. Princeton: Princeton University Press, 2009.

Angrist & Pischke's four questions, cont.

- (3) What is your identification strategy?
  - How do you use your observational data to approximate a real experiment?
  - Often hinges on the ability to construct a "reasonable" counterfactual.

- (4) What is your mode of statistical inference?
  - What is the population to be studied, the sample to be used, and what are the assumptions to be made when constructing standard errors for your coefficient estimates?

Angrist, JD, and J-S Pischke. *Mostly Harmless Econometrics*. Princeton: Princeton University Press, 2009.

Selection bias: the need for a good counterfactual

- What if we simply compare outcomes (say, whether a species survives, or not) for ESA-listed species and non-listed species?
- Observed difference in outcomes = average effect of listing on listed species + *selection bias*
- Selection bias
  - Treatment and control groups differ due to factors that also affect a policy/program's outcomes.
  - In this example: pre-listing difference in survival probability between unlisted and listed species.
  - If listed species were less likely to survive *ex ante*, then selection bias would be negative.
  - If listed species were more likely to survive, then selection bias would be positive.

Experiments in environmental economics

- Random assignment to control/treatment groups solves the selection problem (randomized experiments are the "gold standard" in empirical analysis).

- Until recently, not much experimental work (in the field) by economists, including environmental economists – this has changed dramatically.

- Two recent examples:
  - Kremer et al. (2011). Spring Cleaning
  - Jessoe and Rapson (2014). Knowledge is (less) power

When experiments aren't possible/desirable, what next?

- Design an empirical approach that tests your hypothesis in a manner that replicates, as closely as possible, the conditions of a controlled experiment.

- Keep the methods as straightforward/simple as possible.
  - Interpretation of estimates should not be heavily "model dependent"
  - Hence the emphasis on linear regression, even where earlier analysts might have worried more about the downsides to this class of approaches.

- Be willing to trade fancy models for robustness of simpler ones.

Natural experiments in environmental economics

- A natural experiment takes advantage of treatment and control groups created by nature, chance, or exogenous policy shifts, and exploits the variation between these groups to estimate the effect of interest.

- Examples:

  - Libecap and Lueck (2011) analyze the effect of land demarcation systems on property values, exploiting variation in Ohio related to post-Civil-War land grants.

  - Kotchen and Grant (2011) analyze the effect of daylight savings time on electricity consumption, exploiting variation in Indiana counties' adoption of DST.

Regression models

- Regression models with flexible controls for potential confounders – those variables that might mask causal effects of interest.

- Typical models of this type include sets of "fixed effects" for both the spatial and intertemporal units of interest, rather than (or in addition to) a rich set of descriptive covariates.

- Controlling for observables isn't enough – must also control for potentially confounding *unobservable* heterogeneity.

Examples of regression models

- Olmstead et al. (2013) – estimate the impact of shale gas development in PA on water quality.
  - Include fixed effects for each water quality monitor, and each month (Jan. 2000 - Dec. 2011). Controls for average pollutant levels observed at each monitor over the period, and average levels observed at all monitors in each time period.
- Olmstead and Sigman (ongoing) – estimate the impact of drought on economic activity, and the mediating influence of dams.
  - Include fixed effects for each 10km x 10km grid cell (whole world, less areas with no lights for the whole period), and for each year.

Instrumental variables (IV) models

- Identify a variable, or set of variables, that is correlated with your treatment of interest, but otherwise independent of potential outcomes (technically, uncorrelated with the unexplained variation in outcomes).

- Use these variables as “instruments” to first obtain an estimate of the treatment variable (which no longer contains the confounding variation), and then in a second stage, estimate the effect of interest.

Some examples of IV models

- Pitt et al. (2005)
  - Estimate the impact of indoor air pollution (PM from cooking) on women's health in Bangladesh.
  - But households may allocate cooking to women in poorer health (e.g., older), which could bias estimates.

- Olmstead and Sigman (2015)
  - Estimate the effect of being upstream of an international border on the intensity with which countries dam rivers.
  - Treaties could mitigate any observed "common property" problems.
  - But some of the same things that drive damming of rivers may also drive treaty formation.

Difference-in-difference type models

- Difference-in-differences
  - Data on treated vs. control observations, pre vs. post treatment.
  - Calculate the change in outcomes among treated group between the two periods, and subtract from that the change in outcomes among the control group.

- Matching
  - Match the treatment group observations to otherwise "very similar" observations that did not receive the treatment.
  - Use these matches to statistically construct a counterfactual control group.

- Regression Discontinuity
  - Assignment to the treatment is based on the value of an observed covariate, and whether that value lies on one side or the other of a fixed threshold.

Some examples of DID-type models

- **DID**: Bennear (2007) examines whether "management-based regulation" affects firms' releases of toxic chemicals. She compares pre/post regulation differences in releases among plants covered by these regs, with pre/post differences among plants not covered.

- **Matching**: Ferraro et al. (2007) examine whether ESA listing affects species' endangerment status, using matching. The matches are made using taxonomy and size, pre-treatment endangerment status, number of scientific pubs on a species, League of Conservation Voters scores of state delegations.

- **RD**: Chay and Greenstone (2005) examine the effects of air pollution (PM) on housing values, exploiting the discontinuity in regulation that occurs between attainment/nonattainment counties under the CAA.

Concluding thoughts

- Empirical economists who study environmental amenities and environmental policy use "large-N" statistical methods – we call this practice "econometrics," but the tools resemble those in other fields.

- One important difference may be the emphasis on causal inference using observational data.
  - Experiments are still the "gold standard"
  - But many interesting/important questions can't be explored through field experiments.
  - Economists have had to adopt (from other disciplines) and create methods to bring some of the qualities of controlled experiments to observational studies.