Analzying small sample experimental data

Dr. Dominik Duell, University of Essex

Course Outline

Experimental research often generates only a few observations for data analysis. Researchers conducting a pilot study, need to infer from little data whether fielding the main experiment is worthwile or adjustments are neccessary. Ethically challenging research sometimes is not allowed to broaden data collection beyond a handful of subjects. Budget constraints severly limit the number of observations per treatment. We often work with sample sizes for which standard parametric methods building on particular distributional assumptions and asymptotic theory are not appropriate. When researchers are unable to increase their sample size, or when they are simply unwilling to walk away from research questions on rare phenomena, it is essential to understand whether and how small-N studies run into problems with respect to statistical inference. In short, researchers need to know about statistical methods appropriate to learn from small samples to be more confident in their findings.

This course introduces methods for data exploration and statistical analysis of small samples. It combines non-parametric methods with re-sampling and simulation tools. For an estimate of a treatment effect, non-parametric methods require fewer assumptions about the underlying populations. Those methods can easily be paired with re-sampling methods to obtain the distribution of statistics in situations where small samples do not meet distributional assumptions or where the theory needed to support parametric methods is intractable. Simulation methods paired with appropriate visualizations allow us to meaningfully explore the raw data itself, to investigate the small sample properties of estimators, to draw descriptive inference, or to gain intuitions about which inferences may generalize to the broader population.

Schedule

Session 1: Introduction to small n-studies, experimental design, and statistical inference

Topics:

- What is a small sample? Of Guinness beer, t-, and z-scores
- Experimental design: treatment effects, randomisation, and statistical power
- Small sample properties of standard estimators: when do few observations pose problems?
- Basics in power analysis, simulations, and re-sampling in Stata and R

Contents:
Some history of statistics, it started with experimental data; theoretical properties of standard estimators when samples are small; demonstration of estimation bias on sample data set and simulations; introduction to the Rubin causal model, estimation of treatment effects, and the implication of randomisation techniques on statstical analysis; introduction of the concept of statistical power and evaluation of its dependency on sample size; introduction to power analysis and exercise with sample data set; introduction to simulations and re-sampling in Stata and R

Readings:

- Fisher Box, Joan: Guinness, Gosset, Fisher, and Small Samples, Statistical Science 2(1), pp.45-52, 1987

Button, Katherine et al, Power failure: why small sample size undermines the reliability of neuroscience, Nature Reviews Neuroscience 14(5), 2013

Gerber, Allan and Green, Donald, Field experiments, Chapters 2 and 3, Norton, 2012

List, John et al, So you want to run an experiment, now what? Some simple rules of thumb for optimal experimental design, Experimental Economics 14(4), pp.439-57, 2011

Wilcox, Rand: Sample size and statistical power, in: Nezu and Maguth, Evidence-Based Outcome Research

Greene, Econometric Analysis, Chapter 2 and 14

Session 2: How to make the estimation of treatment effects more robust: Non-parametric methods I

Topics:

Zeros and ones: hypothesis testing and confidence intervals for dichotomous data

Rankings exploited: one- and two-sample location and dispersion problems

Exactly: comparing success probabilities

Expressing relationships: alternatives to correlation coefficients

Contents:
Binomial test, Sign test, Wilcoxon sign rank test, Wilcoxon/Mann-Whitney rank sum test, Kolmogorov-Smirnov test of equality of distributions, Tukey confidence interval, Fisher exact test binomial; Spearman R, Kendall Tau, Somers' D; applications to sample data set; replication of results from parametric tests presented in sample studies and comparison to results from non-parametric tests; problem set on computation and interpretation of test statistics.

Readings:

Hollander, Mylesa and Wolfe, Douglas: Nonparametric statistical methods, selections from chapter 2, 3, 4, and 8, Wiley, 2013

Session 3: How to make the estimation and display of conditional treatment effects more robust: Non-parametric methods II

Topics:

Regressions re-run distribution-free: testing for the slope, slope estimator, confidence bands for the slope estimator

Kolmogorov confidence bounds for distribution functions

Statistics is all local: some thoughts on local averaging, local smoothing, kernel smoothing

Contents: Introduction of Theil statistic and Theil-Sen estimator; Kolmogorov confidence interval; some considerations about local averaging, local smoothing, and kernel smoothing; application of averaging and smoothing techniques to sample data set; graphing of smoothing techniques; problem set on computation and interpretation of test statistics.

Readings:

Hollander/Wolfe selections from chapters 9 and 11

Session 4: Finding appropriate estimators and augmenting experimental data: Simulations and re-sampling

Topics:

Simulate it: Monte Carlo experiments, bootstrapping, and permutations

Simulate small sample properties: how to visualize bias and precision of standard estimators and finding appropriate methods for the experimental data at hand?

Assessing the performance of non-parametric tests and estimators for the experimental data at hand

Contents:
Some theory behind simulations and bootstrapping method; simulations to explore small sample properties of parametric and non-parametric methods; evaluation of small sample behavior of bootstrapping method; contrasting bootstrapping method and Monte Carlo experiments in usefulness for small sample statistical analysis; various programming exercises to run simulations and bootstrapping in Stata and R

Readings:

Fox, John, Applied regression analysis and generalized linear models, Chapter 21:

Bootstrapping Regression Models, 2008

Hendry, David, Monte Carlo Experimentation in Econometrics, in: Griliches and Intriligator, Handbook of Econometrics Volume II, 1984