Interrupted Time-Series

• What is Interrupted Time Series (ITS)?
  – Rationales
  – Designs
  – Analysis
What is ITS?

• A series of observations on the same dependent variable over time

• Interrupted by introduction of a treatment at a particular point in time.

• If the treatment has a causal impact, the post-intervention series will have a different level or slope than the pre-intervention series
The effect can be a change in intercept
Interrupted Time Series Can Provide Strong Evidence for Causal Effects

- Clear Intervention Time Point
- Instantaneous and Huge Effect
- Functional Form is Clear
- No alternative Interpretation Can Easily Explain the Change

**FIGURE 6.1** The effects of charging for directory assistance in Cincinnati.
And Soon to be Classic: What if Everyone in Canada Flushed at Once?

Notice the control time series. More later…
The effect can be a change in slope
Especially with the short preintervention TS, effect not quite as clear-cut, though.

Again, wouldn’t it be nice to have a control time series. More later…
But Most ITS Are Not Ideal

• Treatment introduced gradually, effect delayed or small
  – So threats to causal inference
    • E.g., history (a simultaneous other event)
    • E.g., Reporting change (Orlando Wilson and Chicago Crime)

• Few observations (< 50-100)
  – So threats to statistical inference
    • About trend
    • Estimating autocorrelation
The effect can be delayed in time (sometimes the delay is known, sometimes it is not).
The effects of an alcohol warning label on prenatal drinking

[Graph showing the impact of alcohol warning labels on prenatal drinking over time, with a label indicating the delay estimated from other information.]
Or the Effect Can Be Small
Barcelona Motorcycle Helmet Law Experiment

Results suggested that injury cases on small motorcycles (solid line) decreased after the law was implemented.

Again, notice the control time series, more later.
And the Time Series Can be Very Short
Main NAEP 4th grade math scores by year: Public and Catholic schools
Additional Problems with ITS

• Implementation of intervention not immediate (usually spanning several years)
  – NCLB

• Plus, other possible threats to validity
Threats to Validity: History

• With most simple ITS, the major threat to internal validity is history—that some other event occurred around the same time as the intervention and could have produced the same effect.

• Possible Design Improvements:
  – Add control time series (more detail later)
    – control group time series
    – nonequivalent dependent variable
  – The narrower the intervals measured (e.g., monthly rather than yearly), the fewer the historical events that can explain the findings within that interval.
Threats to Validity: Instrumentation

• Instrumentation: the way the outcome was measured changed at the same time that the intervention was introduced.

  – In Chicago, when Orlando Wilson took over the Chicago Policy Department, he changed the reporting requirements, making reporting more accurate. The result appeared to be an increase in crime when he took office.

  – It is important to explore the quality of the outcome measure over time, to ask about any changes that have been made to how measurement is operationalized.
Threat to SCV

• When a treatment is implemented slowly and diffusely, how to specify a time point at which the intervention “took effect”
• Autocorrelation is biased downwards in small TSs
• Estimating trend, especially nonlinear, can require large samples
• Estimating random effects (e.g., when you have one time series for each school or each client) can require large samples
Construct Validity

• Reactivity threats (due to knowledge of being studied) are often less relevant if archival data are being used.

• However, the limited availability of a variety of archival outcome measures means the researcher is often limited to studying just one or two outcomes that may not capture the real outcomes of interest very well
External Validity

• The essence of external validity is exploring whether the effect holds over different units, settings, outcome measures, etc.

• In ITS, this is only possible if the time series can be disaggregated by such moderators, which is often not the case.
Improving the Basic ITS

• Adding a (usually nonequivalent) control group time series
• Adding a nonequivalent dependent variable
• Adding treatment manipulations (e.g., removals)
• Increasing sample size
  – More observations over time
  – More time series
Adding Control Group Time Series
And Soon to be Classic: What if Everyone in Canada Flushed at Once?

Here the control TS is same data from the day before
Barcelona Motorcycle Helmet Law Experiment

Here the control TS is same data for large motorcycles (law passed years ago covering them, so would not be expected to change)
Project Hope (Scholarships in Georgia if GPA \geq 3.00)

Here the control group is (a) other states in the US Southeast, and (b) US data.
Adding a nonequivalent dependent variable to the time series

NEDV: A dependent variable that is predicted not to change because of treatment, but is expected to respond to some or all of the contextually important internal validity threats in the same way as the target outcome.
Example: British Breathalyzer Experiment

• Intervention: A crackdown on drunk driving using a breathalyzer.

• Presumed that much drunk driving occurred after drinking at pubs during the hours pubs were open.

• Dependent Variable: Traffic casualties during the hours pubs were open.

• Nonequivalent Dependent Variable: Traffic casualties during the hours pubs were closed.

• Helps to reduce the plausibility of history threats that the decrease was due to such things as:
  – Weather changes
  – Safer cars
  – Police crackdown on speeding
Note that the outcome variable (open hours on weekend) did show an effect, but the nonequivalent dependent variable (hours when clubs were closed) did not show an effect.
Example: Media Campaign to Reduce Alcohol Use During a Student Festival at a University (McKillip)

- Dependent Variable: Awareness of alcohol abuse.

- Nonequivalent Dependent Variables (McKillip calls them “control constructs”):
  - Awareness of good nutrition
  - Awareness of stress reduction

- If the effect were due to secular trends (maturation) toward better health attitudes in general, then the NEDVs would also show the effect.
Only the targeted dependent variable, awareness of responsible alcohol use, responded to the treatment, suggesting the effect is unlikely to be due to secular trends in improved health awareness in general.
Adding Treatment Introduction and Removal
Example: Lambert

Teaching children to raise hands and be called on when answering questions
Multiple Baselines on Different Dependent Variables
Example: Chorpita

- A child with difficulties attending school, with symptoms including
  - Somatic complaints
  - Tantrums and anger
  - Crying

- Intervention was a behavioral extinction and reinforcement schedule

- Multiple baseline adding treatment for each of the three symptoms over time.
Initially, only somatic complaints were targeted.

Then, both somatic complaints and anger/tantrums were targeted.

Finally, all three sets of symptoms were targeted in the third phase.
Multiple Baselines on Different Units
Example: Blandford and Lloyd

• Two learning disabled boys

• Intervention: A self-instructional card with seven instructions on how to improve handwriting.

• Outcome: Percent of possible points on a handwriting test

• Multiple Baseline: Intervention was introduced at two different times for the two boys.
The effects of screening for phenylketonuria retardation