From Theory to Computation: A Simulation-Based Approach for Difference-in-Differences Validation

ECON 383: Causal Inference

Augusto Gonzalez-Bonorino

Motivation

- Causal queries are complex
- RCTs are reliable, but not generalizable nor often feasible
- Foundational assumptions are often untestable
- Reliance on expert intuition and heuristics can lead to misinterpretations
- Growing focus on computational methods to embrace complex relationships
- Career goals and research interests

Main Idea

- Explore general methods for simulating DGPs
- Parametrize key sources of bias in panel datasets
- Simulation as a technique for “stress testing” causal models
- Systematic exploration of Difference-In-Differences robustness to selected biases

Literature Review

- RCTs have been the gold standard

Literature Review

- RCTs are reliable but fail to generalize
- Traditional methods rely on expert intuition, institutional knowledge, and are not generalizable
- Sensitivity analysis methods have been evolving rapidly
  - R^2 parametrization, Coefficient stabilization, honestDiD, …
- ML and Deep generative techniques have recently been proposed for synthetic data validation
  - Credence, GANITE, GAIN, GANs, Monte Carlo, …
- Most recent efforts try to combine RCTs and observational methods

Methodology and Contribution

```
Function generate_panel_data:
    Input: n_units, n_time, treatment_start_period, treatment_effect,
           selection_bias_intensity, heterogeneity_intensity,
           time_varying_confounder_intensity, trend_difference, noise_sd

    Initialize panel_data with unit and time dimensions
    Define post-treatment period based on treatment_start_period

    Generate observed_covariate as a random normal variable
    Create unobserved_effect based on heterogeneity_intensity
    Simulate time_varying_confounder as a function of time
            and observed_covariate

    Assign treatment based on post period and selection_bias_intensity
    Define control and treatment group trends

    Calculate outcome incorporating treatment_effect, biases, and random noise
    Return panel_data
```

Results & Implications

- Unadjusted 2-way FE implementation of DiD
- Robust to selection and unit-heterogeneity as the literature suggests
- Sensitive to time-varying confounders and parallel-trends violation
- Note relatively small SEs for largest biases

Experiment	Mean Estimate	Mean Diff.	Mean SE
Unbiased Balanced Panel	2.983	-0.017	1.212
Unbiased Long Panel	3.001	0.001	1.904
Unbiased Short Panel	3.033	0.033	0.783
Selection Bias	2.998	-0.002	0.548
Time-Varying Confounders	4.756	1.756	0.107
Parallel Trends	28.004	25.004	0.821
Heterogeneity Bias	3.002	0.002	0.821

Table 1: Summary of Experiment Results

Panel Structure Experiments

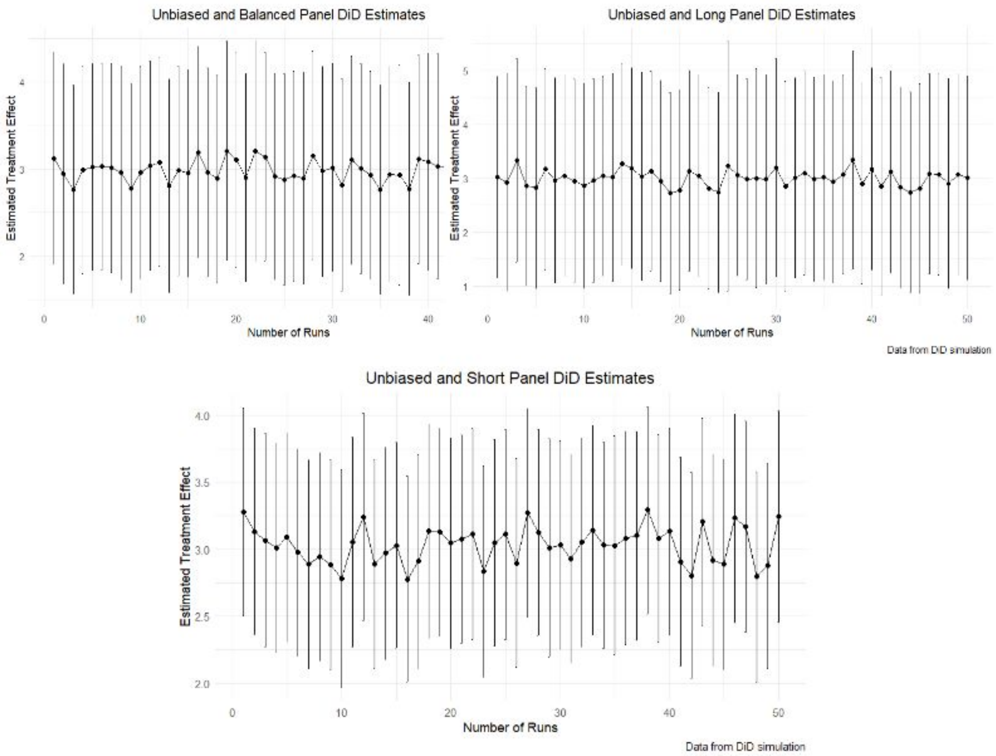

Figure 1: DiD Estimates for Different Panel Structures

Selected Biases Experiments

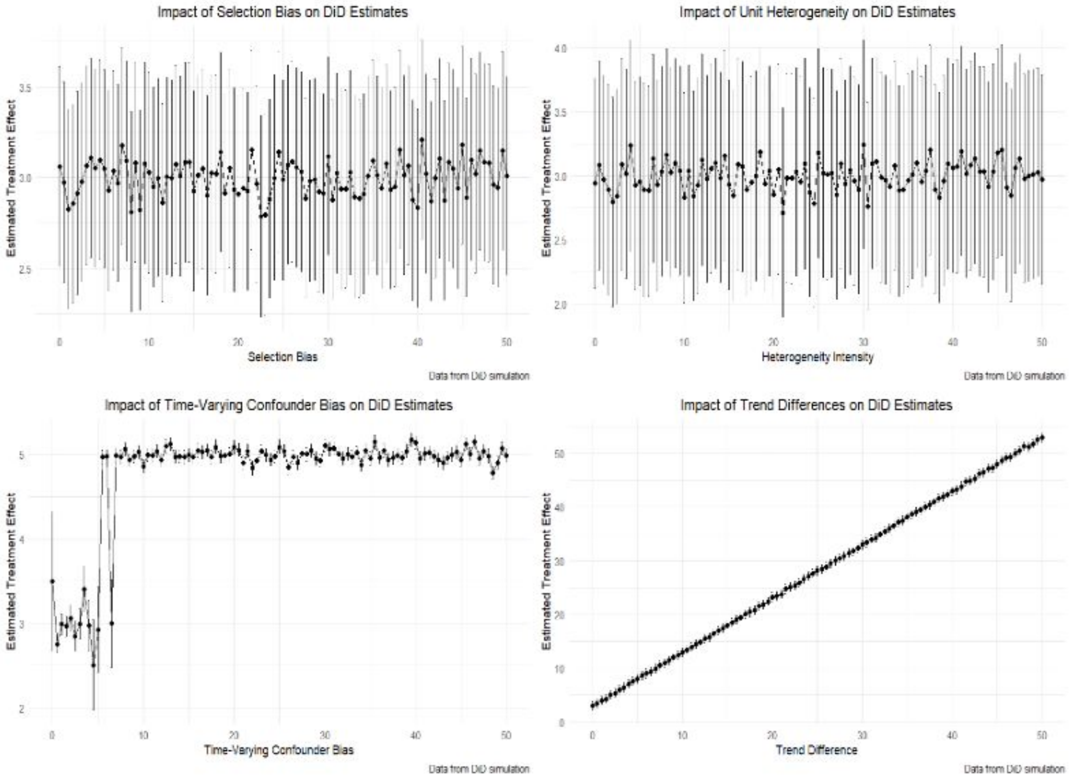

Figure 2: Impact of Various Biases on DiD Estimates

Taxonomy

Traditional Approaches

Key Methods: Within-transformation, TSCS, Hausman tests, Placebo tests.
Advantages: Straightforward, well-understood, easy implementation.
Disadvantages: Indirect testing, reliant on data quality and expert intuition, doesn't conclusively prove assumptions.

Sensitivity Analysis

Key Methods: Manski Bounds, Oster’s approach, R^2 parametrization.
Advantages: Nuanced understanding of model dependence, quantifies uncertainty and confounder strength in the context of the study.
Disadvantages: Complex calculations, challenging to interpret, context-specific

Simulation Approaches

Key Methods: Bootstrapping, Monte Carlo simulations.
Advantages: Directly tests model robustness, uncovers hidden limitations.
Disadvantages: Requires careful scenario design, computationally intensive, generalization might prove uninformative

Limitations & Future Work

- Extension to Other Models: Applying this methodology to a broader range of econometric models.
- Deepening Realism: Enhancing simulations to better mirror complex, real-world datasets.
- Cumulative Bias Effects: Exploring the interplay and cumulative impact of multiple biases.
- Empirical Relevance: Ensuring future research addresses practical, real-world econometric challenges.

Thank You!