

Unifying Regression-based and Design-based Causal Inference in Time-series Experiments and Crossover Experiments

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Abstract

Part I: Time-series experiments, also called switchback experiments or N-of-1 trials, play increasingly important roles in modern applications in medical and industrial areas. Under the potential outcomes framework, recent research has studied time-series experiments from the design-based perspective, relying solely on the randomness in the design to drive the statistical inference. Focusing on simpler statistical methods, we examine the design-based properties of regression-based methods for estimating treatment effects in time-series experiments. We demonstrate that the treatment effects of interest can be consistently estimated using ordinary least squares with an appropriately specified working model and transformed regressors. Additionally, we show that asymptotically, the heteroskedasticity and autocorrelation consistent variance estimators provide conservative estimates of the true, design-based variances. This part is based on <https://arxiv.org/pdf/2510.22864>

Part II: Crossover designs randomly assign each unit to receive a sequence of treatments. By comparing outcomes within the same unit, these designs can effectively eliminate between-unit variation and facilitate the identification of both instantaneous effects of current treatments and carryover effects from past treatments. They are widely used in traditional biomedical studies and are increasingly adopted in modern digital platforms. However, standard analyses of crossover designs often rely on strong parametric models, making inference vulnerable to model misspecification. We unify the analysis of crossover designs using least squares, with restrictions on the coefficients and weights on the units. Based on the theory, we recommend specifying the regression function, weighting scheme, and coefficient restrictions to assess identifiability, construct efficient estimators, and estimate variances in a unified manner. This part is based on <https://arxiv.org/pdf/2511.09215>