

Identification and Estimation of Survivor Average Causal Effect with Exposure-induced Confounders

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Abstract

In longitudinal clinical and epidemiological studies, evaluating causal effects is frequently complicated by truncation by death, which can induce severe selection bias if analyses are restricted only to observed survivors. The Survivor Average Causal Effect (SACE), defined within the principal stratum of "always-survivors," offers a rigorous causal estimand to address this issue. However, identification of the SACE is challenging. Existing identification strategies generally face a methodological impasse: they either rely on stringent pre-exposure surrogate conditions, require structural separability assumptions that strictly prohibit the existence of exposure-induced confounders, or accommodate such confounders only at the cost of redefining the target subpopulation. To bridge this gap, we propose a novel path-specific framework that identifies the traditional SACE in the presence of exposure-induced confounders without requiring surrogate variables or modifying the original estimand. We decompose the SACE into two mechanistically meaningful components, corresponding to the causal pathways not through and through the exposure-induced confounders, respectively. This decomposition not only clarifies the dynamic causal mechanisms obscured by post-treatment confounding but also coincides existing separable effects frameworks as special cases when the intermediate variable does not affect the outcome. Furthermore, we develop a multiply robust estimator for empirical inference and demonstrate the practical utility of our proposed methodology through an application to a chronic obstructive pulmonary disease (COPD) study.

Keywords: SACE, Truncation by death, Exposure-induced confounders, Principal stratification, Multiply robust estimation.