Web-based simulation application to optimize design and analysis decisions for studies of the health impacts of policies and programs

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Background

- Large-scale policies and programs, such as violent crime reduction initiatives and economic development projects have substantial influences on the health of the population in the United States.
- Remarkably, the health effects of most policies and programs are never assessed, particularly those not designed to influence health.
- The rare instance that the post-implementation health effects of a program or policy are examined, current approaches to studying effects have major limitations.
- The choice of study design and analysis approach has been informed by general frameworks, but more rigorous quantitative assessment of which approaches are best to answer the scientific question of interest would greatly improve study quality.

Why does this project matter?

- Policy effects estimated using an inappropriate study design or analysis can result in policy recommendations that are incorrect and unsuitable.
- We establish a publicly available web-based simulation generator that will allow any researcher assessing health impacts to identify the optimal study design and analysis combination for a specific question about the impact of a program or policy, and thereby improve the quality of scientific knowledge on health impacts.

How the Simulator Works

1. Input information about the policy or program, study population, outcome frequency, confounders, and relations between variables
   - Through a simple graphical user interface, users describe their data and study question.
   - The simulator tests a wide variety of study designs and analyses to determine the optimal approach.
   - Based on this information, the software will generate a simulated population with a known intervention effect.
   - Sensitivity tests were used to determine the minimum necessary user input.
   - Scripts can be applied to real data (if available) to parameterize the simulations with less user input.

Example: We planning a study of the effect a violence reduction program on the incidence of violence-related deaths and injuries. Of 1000 census tracts, the 300 with the highest levels of baseline violence were targeted for the intervention. Confounders include demographics and baseline violence. We test a hypothesized effect of 1,488 violent incidents per 100,000 person-years.

2. Select the causal quantities of interest and the types of study designs and analyses to be considered
   - The simulator will apply all combinations of selected study designs and analyses to the simulated data to estimate the effect.
   - Design options include sampling and matching.
   - Analysis options include machine learning algorithms and parametric and semi-parametric estimating equations and substitution estimators.
   - Offers basic default mode and advanced user specifications.

Example: We are interested in estimating the average decline in violence-related deaths and injuries attributable to the program among tracts receiving the intervention. We consider designs that incorporate all 700 non-intervention areas as controls, a random sample of controls, or controls matched to treated neighborhoods on baseline violence or demographics. We consider analyses such as G-computation, treatment weighting (IPTW) and targeted minimum loss-based estimation (TMLE), and both parametric and semiparametric estimation methods.

3. Submit and watch the performance metrics converge!
   - The optimal design-analysis combination is defined as the method with the lowest mean squared error (MSE).
   - Example: The simulator compares the performance of all combinations of study designs and analyses selected in (2). These approaches are applied to the simulated population many times, and the estimates are compared with the known simulated effect to determine the MSE.

Simulator Results

<table>
<thead>
<tr>
<th>Performance rank of ZER</th>
<th>Design</th>
<th>Analysis</th>
<th>Bias</th>
<th>Var</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All 700 controls</td>
<td>Parametric TMLE</td>
<td>6</td>
<td>0.0128</td>
<td>0.0132</td>
</tr>
<tr>
<td>2</td>
<td>All 700 controls</td>
<td>Semi-parametric TMLE</td>
<td>5</td>
<td>0.0112</td>
<td>0.0135</td>
</tr>
<tr>
<td>2</td>
<td>All 700 controls</td>
<td>Parametric IPTW</td>
<td>7</td>
<td>0.0152</td>
<td>0.0154</td>
</tr>
<tr>
<td>21</td>
<td>100 controls matched on demographics</td>
<td>None</td>
<td>147</td>
<td>0.0147</td>
<td>0.2318</td>
</tr>
<tr>
<td>22</td>
<td>All 700 controls</td>
<td>Parametric G-comp</td>
<td>202</td>
<td>0.0136</td>
<td>0.4021</td>
</tr>
</tbody>
</table>

4. Identify the top-performing methods
   - Identify top-performing design and analysis combinations for the study example.
   - Example: In examining the impact of the violence reduction program, general guidelines might have suggested an unmatched design with parametric IPTW or G-computation, or matching. However, simulation results indicated a different design and the resulting approach had lower bias and variance. The optimal design and analysis used all non-intervention areas as controls and parametric targeted minimum loss-based estimation (MSE: 0.0132). In this case, the methods suggested by general guidelines were more biased and less efficient.

Summary

- The choice of the study design and analysis approach to assess health effects of policies and programs is typically informed by general guidelines, and thus not always optimal.
- We have developed a web-based simulation generator to allow investigators to choose the best study design and analysis for their question.
- The example results illustrate how a simulation approach to selecting an optimal design and analysis for assessment of the health impacts of policies and programs can improve the quality of these endeavors.

Simulators, if well calibrated, can have the potential to substantially improve the rigor of studies of the health effects of policies and programs.