Overview

We utilized data from a nationally representative longitudinal study in the estimation of behavioral transitions and inference for tobacco use in the U.S. These estimates were then used to validate a microsimulation model aimed at accurately projecting downstream prevalence of product use.

Background and Study Design

- **Tobacco use** is the leading cause of preventable disease, disability, and death in the United States.
- The U.S. witnessed a **dramatic increase** in the use of electronic nicotine delivery systems (ENDS) in cigarettes in the last decade. Most notably, the year 2019 observed a boom in the use of JUUL among high school-aged youth.
- **Simulation modeling** provides a useful approach to addressing and understanding how traditional cigarettes and e-cigarettes interact and affect the prevalence of tobacco use within our ecosystem.
- We fit a Markov multi-state model (MMSM) for participants in Waves 1-5 of the Population Assessment of Tobacco and Health (PATH) longitudinal study in order to inform and update the Simulation of Tobacco and Nicotine Outcomes and Policy (STOP) model, a microsimulation model used to project effects of tobacco use and cessation over time, including the key behavior of relapse.
- Results from the MMSM were supplemented with results from mixed-effects regression which allowed for the quantitative inference of the effect of covariates on use behaviors.

Data

<table>
<thead>
<tr>
<th>ID</th>
<th>WAVE</th>
<th>SEX</th>
<th>AGE</th>
<th>RACE</th>
<th>EDUCATION</th>
<th>RELAPSE</th>
<th>WEIGHT</th>
<th>USE</th>
<th>STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>P0004</td>
<td>1</td>
<td>Male</td>
<td>18-24 years</td>
<td>White</td>
<td>Some college</td>
<td>0</td>
<td>7073.69</td>
<td>NGSF</td>
<td></td>
</tr>
<tr>
<td>P0004</td>
<td>2</td>
<td>Male</td>
<td>18-24 years</td>
<td>White</td>
<td>Some college</td>
<td>1</td>
<td>7073.69</td>
<td>NSCE</td>
<td></td>
</tr>
<tr>
<td>P0005</td>
<td>3</td>
<td>Female</td>
<td>45-64 years</td>
<td>Other</td>
<td>Advanced Degree</td>
<td>0</td>
<td>3096.67</td>
<td>FSNE</td>
<td></td>
</tr>
<tr>
<td>P0569</td>
<td>4</td>
<td>Female</td>
<td>12-14 years</td>
<td>Black</td>
<td>High school or less</td>
<td>0</td>
<td>1322.36</td>
<td>NSCE</td>
<td></td>
</tr>
<tr>
<td>P0569</td>
<td>4.5</td>
<td>Female</td>
<td>15-17 years</td>
<td>Black</td>
<td>High school or less</td>
<td>0</td>
<td>1322.36</td>
<td>NSCE</td>
<td></td>
</tr>
<tr>
<td>P0569</td>
<td>5</td>
<td>Female</td>
<td>15-17 years</td>
<td>Black</td>
<td>High school or less</td>
<td>0</td>
<td>1322.36</td>
<td>NSCE</td>
<td></td>
</tr>
</tbody>
</table>

Methods

Overview of tobacco use states and transitions in the STOP model

Transition probabilities derived from the Markov multi-state model are given by:

\[ P_i(j,t) = P(X_t = j | X_0 = i) \]

where \( j \) describes the state occupied at \( t \).

Covariate effects on transition rates were estimated. The estimate of the hazard, \( \lambda_j(t) \) is given by:

\[ \lambda_j(t) = \frac{\partial P(X_t = j | X_0 = i)}{\partial t} \]

where \( \lambda_j \) is the instantaneous rate of transition from one state to another.

Transition probabilities are computed from these intensities as \( P(t) = \exp(\lambda t) \).

Results

We fit mixed-effects logistic regression models to draw inference on the effects of our covariates on tobacco use:

\[ \logit[E\{Current Tobacco Use | X|] = \beta_0 + \beta_1 \text{Age} + \beta_2 \text{Sex} + \beta_3 \text{Race} + \beta_4 \text{Education} + \beta_5 \text{Num. Relapses}, \]

where \( \beta_{ij} \) is a random intercept for individual \( i \) in the study.

Current tobacco use is interchangeable with current smoking and current ENDS use of which we fit separate models for.

Conclusion

- **Youth tobacco use** was generally more erratic than that of adults with this groups taking particular interest in ENDS/e-cigarettes over traditional cigarettes.
- **Roth mean-squared error (RMSE) and weighted root mean-squared error (WRMSE)** for STOP-projected versus PATH empirical prevalence for smoking and ENDS were < 4% for all four years of simulation. We observed especially great performance on estimates for Year 4-2019 (our primary target of interest due to the boom in JUUL use that occurred during this time).
- With confidence in our results, tax policies intended to influence tobacco use can be introduced into the STOP model, thereby providing decision makers with estimates of the potential impact of these policies.
- Mixed effects models revealed covariate relationships consistent with what was found in Markov multi-state modeling.

We extract odds ratios corresponding to our covariates of interest related to separate outcomes of current smoking (yellow) and current ENDS use (blue) with a reference group of Female, 15-17 yo., White in high school or lower, at a baseline time of 0/relapses observed during the duration of the study. Notably, the effect of age for those ≥25y takes on a reverse effect depending on the tobacco product, further demonstrating the popularity of e-cigarettes in younger populations as opposed to older. ENDS are also highly prevalent among high-school graduate/collage aged individuals opposed to cigarettes. Lastly, assuming a linear effect of time, while cigarettes have become less popular over time, ENDS have become slightly more popular over time, though this positive correlation is not significant.

We fit mixed-effects logistic regression models to draw inference on the effects of our covariates on tobacco use:

\[ \logit[E\{Current Tobacco Use | X|] = \beta_0 + \beta_1 \text{Age} + \beta_2 \text{Sex} + \beta_3 \text{Race} + \beta_4 \text{Education} + \beta_5 \text{Num. Relapses}, \]

where \( \beta_{ij} \) is a random intercept for individual \( i \) in the study.

Current tobacco use is interchangeable with current smoking and current ENDS use of which we fit separate models for.