

## 1 Problem Description and Modeling Objective

In the paper “Estimating treatment effect heterogeneity in randomized program evaluation,”[1] the authors are concerned with “treatment effect heterogeneity” which they define as “the degree to which different treatments have differential causal effects on each unit.” The authors’ objective is to estimate treatment effect heterogeneity in order to (1) select the most effective treatment among a large number of available treatments, (2) design optimal treatments for sub-groups of units, (3) test the existence of treatment effect heterogeneity, and (4) generalize causal effect estimates from a sample to a target population.

## 2 Data Description and Availability of Dataset

The R package `FindIt` includes the data from two well-known randomized evaluation studies in the social sciences that the authors’ apply their model to.[2] Including the dataset `GerberGreen`, which is data from the 1998 New Haven Get-Out-the-Vote field experiment where many different mobilization techniques were randomly administered to voters in the 1998 election. As well as the dataset `LaLonde`, which is data from the national supported work (NSW) program that was a job training program intended to increase earnings of workers conducted from 1975 to 1978 over 15 sites in the United States.

### 2.1 Gerber and Green (1998) New Haven Get-Out-the-Vote

Table 1 provides a preview of the `GerberGreen` dataset. This dataset includes one outcome variable, four treatment variables, and four pre-treatment control covariates. Specifically, `voted98` is a binary outcome variable of whether a registered voter voted or not in the 1998 election; `persngrp` is a binary treatment variable of whether a personal visit of a registered voter was made; `phnscrpt` is a categorical treatment variable with 7 levels (0 - no phone call, 1 - donate blood, 2 - civic appeal, 3 - civic appeal/donate blood, 4 - neighborhood solidarity, 5 - civic appeal/neighborhood solidarity, 6 - close election), for the phone message scripts read to registered voters; `mailings` is an ordinal treatment variable of the number (0-3) of mailings sent to voters; `appeal` is a categorical treatment variable with 3 levels (1 - civic duty, 2 - neighborhood solidarity, 3 - close election) for the content of the appeal made to registered voters; `age` is an ordinal control for the age of the registered voter; `majorpty` is a binary control for whether the registered voter was registered with either the Democratic or Republican party (1) or not (0); `vote96.1` is a binary control for whether the registered voter voted in the 1996 election; `vote96.0` is a binary control for whether the registered voter abstained in the 1996 election.

Of the 14,774 registered voters collected in `GerberGreen`, 5,879 (39.8%), voted in the 1998 election. Figure 1 provides the proportion that voted in the 1998 election by the levels of each of the four treatment types. Whereas, Figure 2 provides the proportion that voted in the 1998 election by the levels of each of the four pre-treatment controls.

Further, Table 2 provides a breakdown of the proportion of registered voters that voted in 1998 by each of the combinations of the four treatment variables present in `GerberGreen`. Note, in the original experiment design there were 193 unique treatment combinations randomly administered to registered voters; however, the authors limited their study to single voter households to avoid interference among voters in the same household and thus only 72 treatment combinations are present in the subsetted data. Finally, Table 3 provides a breakdown of the proportion of registered voters that voted in 1998 by each of the combinations of the pre-treatment control covariates.

Table 1: Gerber and Green (1998) New Haven Get-Out-the-Vote

|       | voted98 | persngrp | phnscript | mailings | appeal | age | majorpty | vote96.1 | vote96.0 |
|-------|---------|----------|-----------|----------|--------|-----|----------|----------|----------|
| 1     | 1       | 0        | 2         | 2        | 1      | 47  | 1        | 1        | 0        |
| 2     | 0       | 0        | 2         | 2        | 1      | 24  | 1        | 0        | 0        |
| 3     | 0       | 0        | 4         | 1        | 2      | 64  | 1        | 0        | 1        |
| ⋮     | ⋮       | ⋮        | ⋮         | ⋮        | ⋮      | ⋮   | ⋮        | ⋮        | ⋮        |
| 14772 | 0       | 0        | 0         | 0        | 2      | 29  | 1        | 1        | 0        |
| 14773 | 0       | 0        | 0         | 0        | 1      | 53  | 1        | 1        | 0        |
| 14774 | 1       | 0        | 0         | 0        | 1      | 74  | 1        | 1        | 0        |

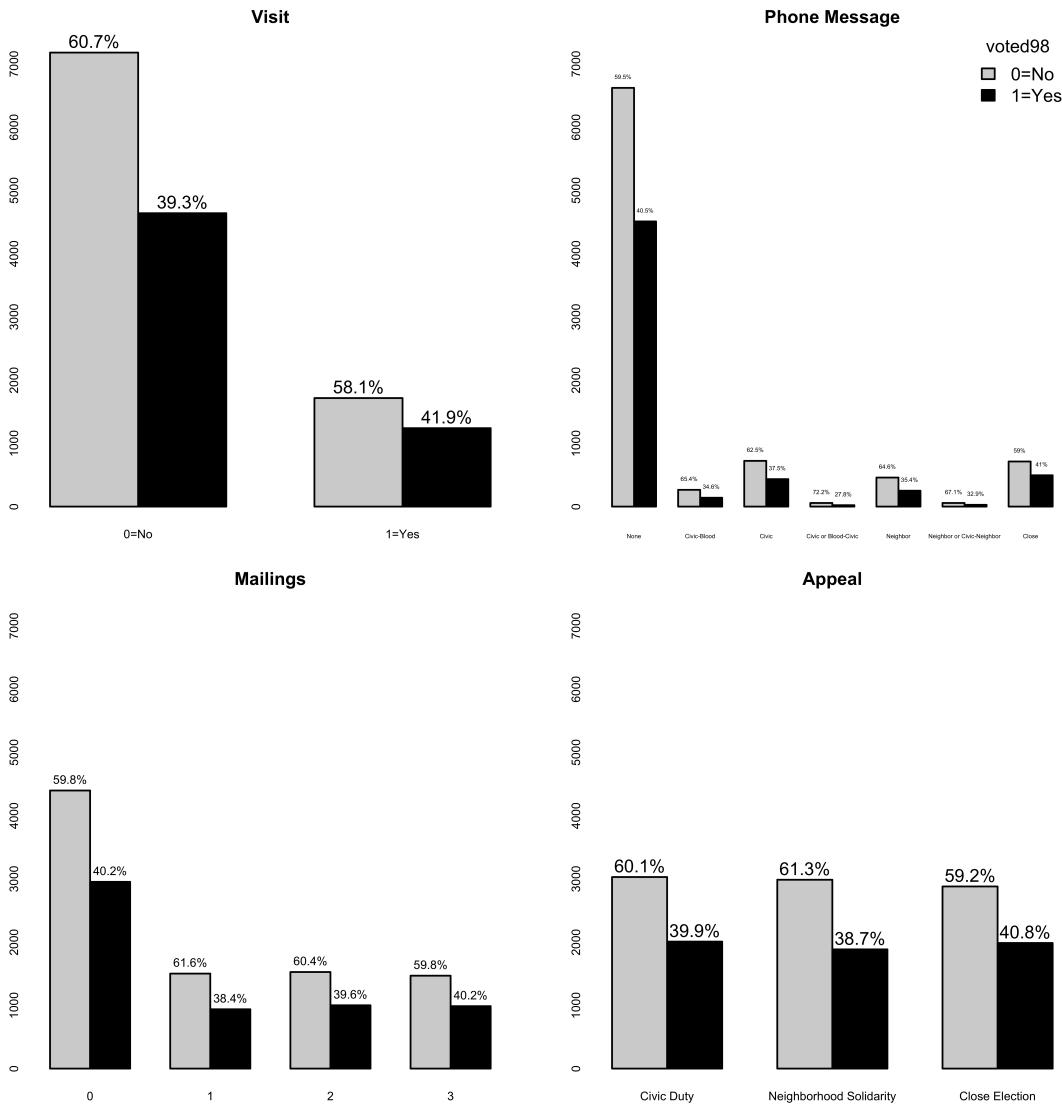


Figure 1: Voting Outcome by Treatment Type

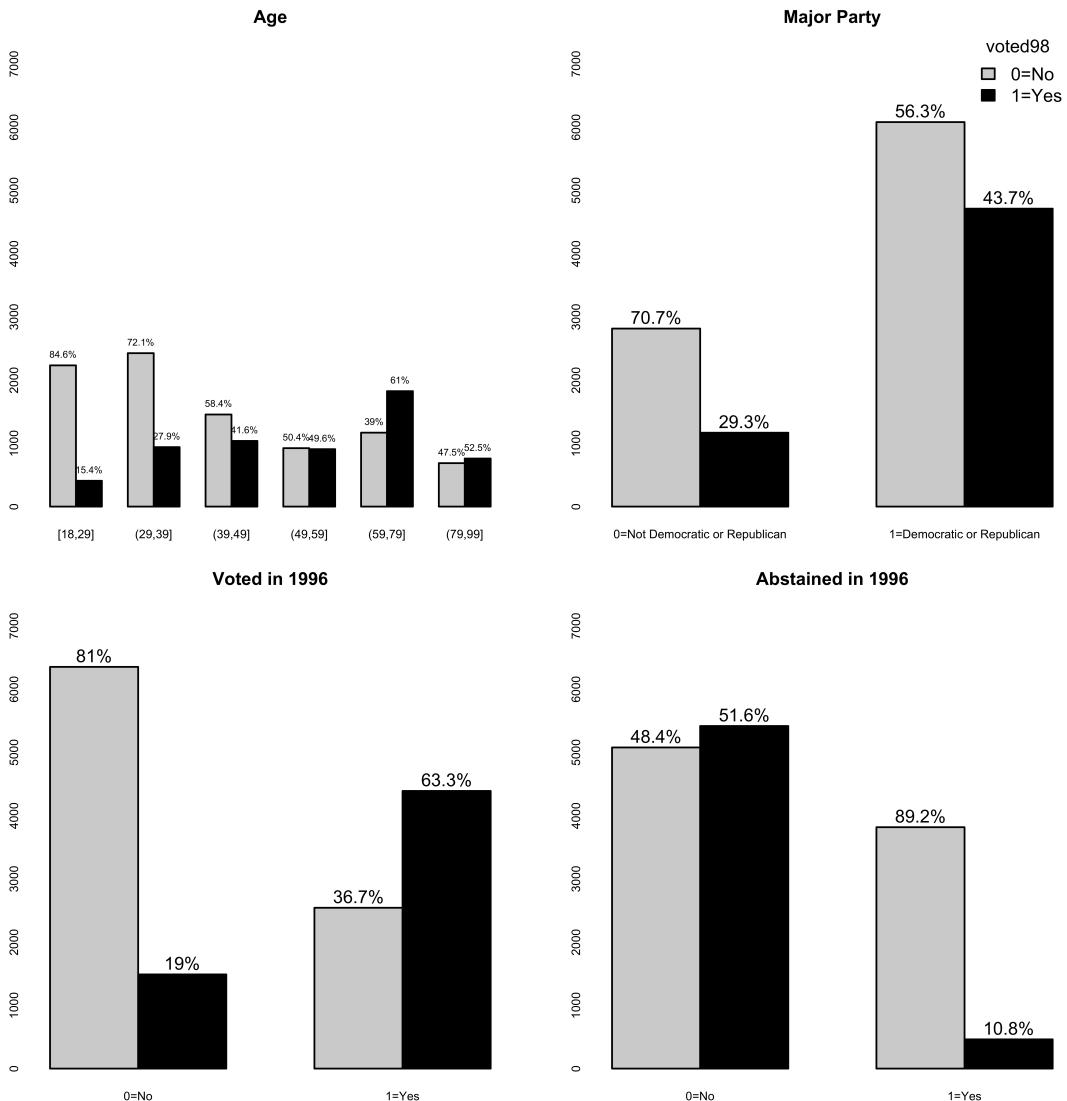


Figure 2: Voting Outcome by Pre-Treatment Control

Table 2: Get-Out-the-Vote Treatment Interactions

| Visit | Phone | Mailings                   | Appeal | Registered              | Voted | Proportion |       |
|-------|-------|----------------------------|--------|-------------------------|-------|------------|-------|
| 1     | Yes   | Civic-Blood                | 1      | Civic Duty              | 13    | 8          | 61.5% |
| 2     | No    | Civic or Blood-Civic       | 1      | Civic Duty              | 12    | 6          | 50.0% |
| 3     | Yes   | Neighbor                   | 2      | Neighborhood Solidarity | 46    | 23         | 50.0% |
| 4     | Yes   | Neighbor or Civic-Neighbor | 2      | Neighborhood Solidarity | 4     | 2          | 50.0% |
| 5     | Yes   | Civic                      | 2      | Civic Duty              | 55    | 26         | 47.3% |
| 6     | Yes   | Neighbor or Civic-Neighbor | 1      | Neighborhood Solidarity | 11    | 5          | 45.5% |
| 7     | Yes   | Civic                      | 0      | Neighborhood Solidarity | 40    | 18         | 45.0% |
| 8     | Yes   | None                       | 1      | Close Election          | 87    | 39         | 44.8% |
| 9     | Yes   | None                       | 0      | Civic Duty              | 506   | 226        | 44.7% |
| 10    | Yes   | None                       | 2      | Close Election          | 112   | 50         | 44.6% |
| 11    | Yes   | None                       | 3      | Civic Duty              | 110   | 49         | 44.5% |
| 12    | Yes   | Neighbor                   | 3      | Neighborhood Solidarity | 45    | 20         | 44.4% |
| 13    | Yes   | None                       | 0      | Close Election          | 431   | 190        | 44.1% |
| 14    | Yes   | Close                      | 1      | Close Election          | 68    | 30         | 44.1% |
| 15    | No    | Close                      | 2      | Close Election          | 244   | 107        | 43.9% |
| 16    | Yes   | None                       | 3      | Close Election          | 89    | 39         | 43.8% |
| 17    | Yes   | Civic                      | 3      | Civic Duty              | 53    | 23         | 43.4% |
| 18    | No    | None                       | 3      | Civic Duty              | 393   | 170        | 43.3% |
| 19    | Yes   | Civic or Blood-Civic       | 2      | Civic Duty              | 7     | 3          | 42.9% |
| 20    | No    | None                       | 3      | Close Election          | 397   | 169        | 42.6% |
| 21    | Yes   | Close                      | 2      | Close Election          | 54    | 23         | 42.6% |
| 22    | No    | None                       | 2      | Neighborhood Solidarity | 421   | 178        | 42.3% |
| 23    | Yes   | None                       | 0      | Neighborhood Solidarity | 411   | 174        | 42.3% |
| 24    | Yes   | Civic                      | 1      | Neighborhood Solidarity | 12    | 5          | 41.7% |
| 25    | Yes   | Civic                      | 2      | Neighborhood Solidarity | 12    | 5          | 41.7% |
| 26    | No    | Close                      | 3      | Close Election          | 250   | 104        | 41.6% |
| 27    | No    | Close                      | 1      | Close Election          | 260   | 107        | 41.2% |
| 28    | Yes   | None                       | 2      | Neighborhood Solidarity | 105   | 43         | 41.0% |
| 29    | No    | None                       | 0      | Close Election          | 1742  | 702        | 40.3% |
| 30    | No    | None                       | 2      | Civic Duty              | 412   | 166        | 40.3% |
| 31    | No    | None                       | 3      | Neighborhood Solidarity | 376   | 151        | 40.2% |
| 32    | No    | None                       | 0      | Civic Duty              | 1772  | 706        | 39.8% |
| 33    | No    | Civic                      | 2      | Civic Duty              | 196   | 78         | 39.8% |
| 34    | No    | None                       | 0      | Neighborhood Solidarity | 1755  | 693        | 39.5% |
| 35    | Yes   | Close                      | 3      | Close Election          | 76    | 30         | 39.5% |
| 36    | No    | None                       | 1      | Close Election          | 386   | 152        | 39.4% |
| 37    | No    | None                       | 1      | Civic Duty              | 438   | 172        | 39.3% |
| 38    | Yes   | None                       | 1      | Civic Duty              | 80    | 31         | 38.8% |
| 39    | No    | Civic                      | 3      | Civic Duty              | 197   | 76         | 38.6% |
| 40    | No    | None                       | 1      | Neighborhood Solidarity | 400   | 154        | 38.5% |
| 41    | Yes   | Civic-Blood                | 0      | Civic Duty              | 39    | 15         | 38.5% |
| 42    | No    | Close                      | 0      | Close Election          | 200   | 76         | 38.0% |
| 43    | No    | Civic                      | 1      | Civic Duty              | 187   | 69         | 36.9% |
| 44    | No    | Neighbor or Civic-Neighbor | 1      | Neighborhood Solidarity | 19    | 7          | 36.8% |
| 45    | Yes   | None                       | 2      | Civic Duty              | 110   | 40         | 36.4% |
| 46    | No    | None                       | 2      | Close Election          | 414   | 150        | 36.2% |
| 47    | Yes   | None                       | 1      | Neighborhood Solidarity | 90    | 32         | 35.6% |
| 48    | Yes   | None                       | 3      | Neighborhood Solidarity | 93    | 33         | 35.5% |
| 49    | No    | Civic-Blood                | 2      | Civic Duty              | 48    | 17         | 35.4% |
| 50    | No    | Neighbor                   | 3      | Neighborhood Solidarity | 207   | 73         | 35.3% |
| 51    | No    | Civic                      | 0      | Neighborhood Solidarity | 208   | 71         | 34.1% |
| 52    | No    | Civic-Blood                | 0      | Civic Duty              | 190   | 64         | 33.7% |
| 53    | No    | Neighbor                   | 1      | Neighborhood Solidarity | 188   | 63         | 33.5% |
| 54    | Yes   | Civic                      | 3      | Neighborhood Solidarity | 9     | 3          | 33.3% |
| 55    | No    | Civic                      | 3      | Neighborhood Solidarity | 52    | 17         | 32.7% |
| 56    | No    | Civic-Blood                | 3      | Civic Duty              | 43    | 14         | 32.6% |
| 57    | No    | Neighbor                   | 2      | Neighborhood Solidarity | 179   | 58         | 32.4% |
| 58    | Yes   | Close                      | 0      | Close Election          | 56    | 18         | 32.1% |
| 59    | No    | Civic-Blood                | 1      | Civic Duty              | 50    | 16         | 32.0% |
| 60    | No    | Civic                      | 1      | Neighborhood Solidarity | 44    | 14         | 31.8% |
| 61    | Yes   | Civic                      | 1      | Civic Duty              | 44    | 14         | 31.8% |
| 62    | No    | Civic                      | 2      | Neighborhood Solidarity | 48    | 15         | 31.2% |
| 63    | Yes   | Neighbor                   | 1      | Neighborhood Solidarity | 45    | 14         | 31.1% |
| 64    | Yes   | Civic-Blood                | 3      | Civic Duty              | 13    | 4          | 30.8% |
| 65    | No    | Neighbor or Civic-Neighbor | 2      | Neighborhood Solidarity | 23    | 7          | 30.4% |
| 66    | No    | Neighbor or Civic-Neighbor | 3      | Neighborhood Solidarity | 21    | 6          | 28.6% |
| 67    | No    | Civic or Blood-Civic       | 2      | Civic Duty              | 29    | 8          | 27.6% |
| 68    | Yes   | Civic or Blood-Civic       | 3      | Civic Duty              | 8     | 2          | 25.0% |
| 69    | Yes   | Civic-Blood                | 2      | Civic Duty              | 9     | 2          | 22.2% |
| 70    | No    | Civic or Blood-Civic       | 3      | Civic Duty              | 17    | 3          | 17.6% |
| 71    | Yes   | Neighbor or Civic-Neighbor | 3      | Neighborhood Solidarity | 7     | 1          | 14.3% |
| 72    | Yes   | Civic or Blood-Civic       | 1      | Civic Duty              | 6     | 0          | 0.0%  |

Table 3: Get-Out-the-Vote Control Interactions

|    | Age     | Major Party | Voted in '96 | Abstained in '96 | Registered | Voted | Proportion |
|----|---------|-------------|--------------|------------------|------------|-------|------------|
| 1  | [18,29] | 0           | 0            | 0                | 417        | 56    | 13.4%      |
| 2  | [18,29] | 0           | 0            | 1                | 458        | 17    | 3.7%       |
| 3  | [18,29] | 0           | 1            | 0                | 267        | 60    | 22.5%      |
| 4  | [18,29] | 1           | 0            | 0                | 630        | 105   | 16.7%      |
| 5  | [18,29] | 1           | 0            | 1                | 458        | 30    | 6.6%       |
| 6  | [18,29] | 1           | 1            | 0                | 411        | 140   | 34.1%      |
| 7  | (29,39] | 0           | 0            | 0                | 334        | 65    | 19.5%      |
| 8  | (29,39] | 0           | 0            | 1                | 300        | 15    | 5.0%       |
| 9  | (29,39] | 0           | 1            | 0                | 335        | 139   | 41.5%      |
| 10 | (29,39] | 1           | 0            | 0                | 757        | 209   | 27.6%      |
| 11 | (29,39] | 1           | 0            | 1                | 779        | 68    | 8.7%       |
| 12 | (29,39] | 1           | 1            | 0                | 861        | 444   | 51.6%      |
| 13 | (39,49] | 0           | 0            | 0                | 149        | 41    | 27.5%      |
| 14 | (39,49] | 0           | 0            | 1                | 201        | 17    | 8.5%       |
| 15 | (39,49] | 0           | 1            | 0                | 276        | 148   | 53.6%      |
| 16 | (39,49] | 1           | 0            | 0                | 464        | 166   | 35.8%      |
| 17 | (39,49] | 1           | 0            | 1                | 503        | 78    | 15.5%      |
| 18 | (39,49] | 1           | 1            | 0                | 901        | 588   | 65.3%      |
| 19 | (49,59] | 0           | 0            | 0                | 89         | 34    | 38.2%      |
| 20 | (49,59] | 0           | 0            | 1                | 114        | 10    | 8.8%       |
| 21 | (49,59] | 0           | 1            | 0                | 200        | 116   | 58.0%      |
| 22 | (49,59] | 1           | 0            | 0                | 286        | 134   | 46.9%      |
| 23 | (49,59] | 1           | 0            | 1                | 371        | 56    | 15.1%      |
| 24 | (49,59] | 1           | 1            | 0                | 772        | 558   | 72.3%      |
| 25 | (59,79] | 0           | 0            | 0                | 77         | 35    | 45.5%      |
| 26 | (59,79] | 0           | 0            | 1                | 143        | 26    | 18.2%      |
| 27 | (59,79] | 0           | 1            | 0                | 359        | 262   | 73.0%      |
| 28 | (59,79] | 1           | 0            | 0                | 272        | 142   | 52.2%      |
| 29 | (59,79] | 1           | 0            | 1                | 523        | 111   | 21.2%      |
| 30 | (59,79] | 1           | 1            | 0                | 1620       | 1249  | 77.1%      |
| 31 | (79,99] | 0           | 0            | 0                | 25         | 8     | 32.0%      |
| 32 | (79,99] | 0           | 0            | 1                | 92         | 11    | 12.0%      |
| 33 | (79,99] | 0           | 1            | 0                | 147        | 108   | 73.5%      |
| 34 | (79,99] | 1           | 0            | 0                | 62         | 32    | 51.6%      |
| 35 | (79,99] | 1           | 0            | 1                | 337        | 23    | 6.8%       |
| 36 | (79,99] | 1           | 1            | 0                | 784        | 578   | 73.7%      |

## 2.2 LaLonde (1996) National Supported Work Study

Table 4 provides a preview of the LaLonde dataset. This dataset includes one binary outcome variable, one binary treatment variable, and ten pre-treatment control covariates. Specifically, `outcome` is a binary outcome variable of whether earnings in 1978 are larger than in 1975; `treat` ... `age` ... `educ` ... `black` ... `hispanic` ... `white` ... `marr` ... `nodegr` ... `log.re75` ... `u75` ... `wts.extrap` ...

## 3 Model and Methods Description

In order to overcome the methodological challenges of (1) extracting useful information from sparse randomized evaluation study data, (2) identifying sub-groups for whom a treatment is beneficial, and (3) generalizing the results of an experiment to a target population, the authors' formulate the estimation of heterogeneous treatment effects as a variable selection problem. Specifically, the paper develops a Squared Loss Support Vector Machine (L2-SVM) with separate LASSO constraints over the pre-treatment and causal heterogeneity parameters, such that the causal heterogeneity variables

Table 4: LaLonde (1986) National Supported Work Study

|     | outcome | treat | age | educ | black | hisp | white | marr | nodegr | log.re75 | u75 | wts.extrap |
|-----|---------|-------|-----|------|-------|------|-------|------|--------|----------|-----|------------|
| 1   | 0       | 0     | 23  | 10   | 1     | 0    | 0     | 0    | 1      | 0        | 1   | 0.83       |
| 2   | 1       | 0     | 26  | 12   | 0     | 0    | 1     | 0    | 0      | 0        | 1   | 1.08       |
| 3   | 0       | 0     | 22  | 9    | 1     | 0    | 0     | 0    | 1      | 0        | 1   | 0.83       |
|     | :       | :     | :   | :    | :     | :    | :     | :    | :      | :        | :   | :          |
| 720 | 0       | 1     | 24  | 10   | 1     | 0    | 0     | 1    | 1      | 8.31     | 0   | 1.02       |
| 721 | 0       | 1     | 33  | 11   | 1     | 0    | 0     | 1    | 1      | 10.13    | 0   | 1.3        |
| 722 | 1       | 1     | 33  | 12   | 1     | 0    | 0     | 1    | 0      | 9.3      | 0   | 1.86       |

of interest are separated from the rest of the variables.

The proposed model is grounded within the potential outcomes framework for causal inference. In this framework, the causal effect of treatment  $t$  for unit  $i$  is defined as  $Y_i(t) - Y_i(0)$ , where  $Y_i$  is the potential outcome for unit  $i$  under treatment or control. Thus, by leveraging the fact that the L2-SVM is an optimal classifier, the proposed model can estimate heterogeneous treatment effects by predicting the potential outcomes  $Y_i(t)$  directly from the fitted model and estimate the conditional treatment effect as the difference between the predicted outcome under treatment status  $t$  and under the control condition.

To fit the proposed model the authors' use an estimation algorithm based on a generalized cross-validation (GCV) statistic. Because of the structure of the proposed model, the SVM becomes a least squares problem on a subset of the data, therefore the L2-SVM is fitted through a series of iterated LASSO fits. Accordingly, the authors' employ an efficient coordinate descent algorithm for the LASSO fits.

## References

- [1] Kosuke Imai and Marc Ratkovic. Estimating treatment effect heterogeneity in randomized program evaluation. *The Annals of Applied Statistics*, 7(1), March 2013.
- [2] Marc Ratkovic and Kosuke Imai. Findit: R package for finding heterogeneous treatment effects, 2012. Available at Comprehensive R Archive Network (CRAN).