ESM 228 Practicum 3

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Practicum 3 Part 5

Does a power analysis (in code) indicate that you will have sufficient power to detect a reasonable treatment effect?

Power Analysis

This analysis explores the minimum detectable effect of the Ventura Water Wise Incentive Program from a fixed sample size. The program has a finite amount of money and rebates are limited to a maximum of $3200 per household. Since the program can only support a maximum number of households, we are interested in determining the minimum effect size that is detectable with a fixed sample size.

Setup power analysis

Population: households in Ventura who qualify for the program and apply to participate; based on application numbers we are estimating this is about 600 households. We are choosing the population to be households that apply for the program because we imagine there are differences across groups who would choose to opt in to this program that make comparing directly between those who apply and those who do not apply challenging. By using households who apply to the program as the population and comparing those who apply and receive a rebate to those who apply and do not receive a rebate, we are trying to account for factors that would result in selection bias.

Water use (water): Residential water use is typically highest in August. Since we have program data from 2016, we will use the average household water consumption in August 2016 to represent average water use. Average customer water use in August 2016 was 94.4 gallons per day. We are assuming that a typical household has somewhere from 2-4 people. Assuming water use is normally distributed with an average of three people per household, mean water use is then 103,368 gallons per year per household or 0.317 acre feet per year per household. Since tthe program data uses acre feet per year, our water use will be acre feet of water per household per year.

Water use variation (u): We are assuming a mean variation in water use equivalent to one person, 34,456 gallons per year or 0.11 acre feet per year. We assume a standard deviation of approximately half a person's average water use or 0.05 acre feet per year.

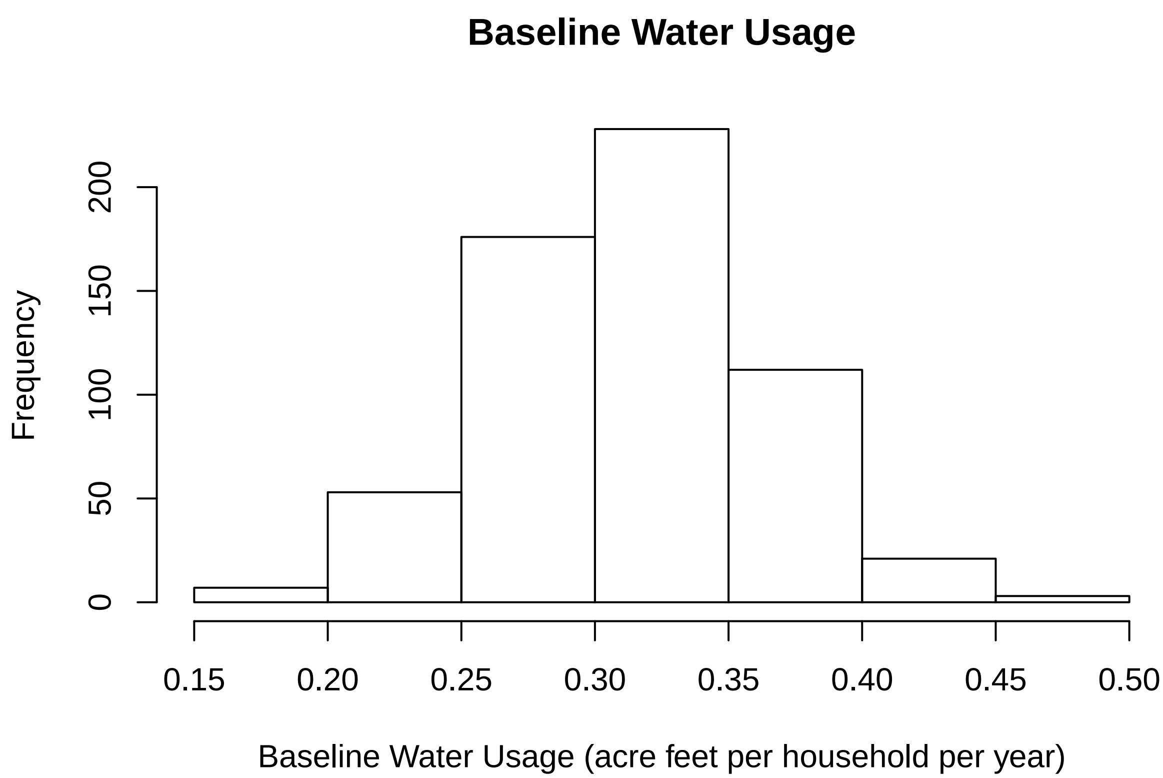
Treatment effect (te): We will be testing for the minimum detectable treatment effect. However, the program estimates that in 2016 50 acre feet of water were saved across the 330 households participating in the program, which is equivalent to a change of 0.157 acre feet per household per year.

Sample size: We are holding the sample size constant at 100 program participants. Based on the program's past years with a large number of applications, we are confident that at least 100 rejected applicants will be available for the control group. Of the 300+ applicants who eventually complete the program, 100 will be chosen at random to serve as the treatment group. For more information see the randomization section.

Test statistic: We are using a difference in differences test statistic. The county collects data on household level water use and therefore we will have the ability to compare water use before the program and after the program for households in treatment and control groups. Further, there can be a lot of variation in water use based on size of the yard, the number of people in the home, efficiency of appliances etc. which makes a difference in means a less favorable test statistic.

```
# declare population
population <- declare_population(
  households = add_level(N=600,
    water = rnorm(n=N, mean=0.317, sd=0.05),
    u= rnorm(n=N, mean= 0.11, sd=0.05))
)

pop <- population()
hist(pop[,2], xlab="Baseline Water Usage (acre feet per household per year)",
     main="Baseline Water Usage", cex=24)
```




```
te <- -0.157 #setting treatment effect
samp_size <- 100 #setting sample size


# potential outcomes:
potential_outcomes <-
  declare_potential_outcomes(
    Y_D_0= water + u,
    Y_D_1= water + u + te)
```

```
po <- potential_outcomes(pop)
kable(po[1:5,], digits=1)
```

households	water	u	Y_D_0	Y_D_1
001	0.4	0.1	0.5	0.4
002	0.3	0.2	0.5	0.3
003	0.3	0.1	0.4	0.3
004	0.2	0.1	0.3	0.2
005	0.3	0.1	0.4	0.3

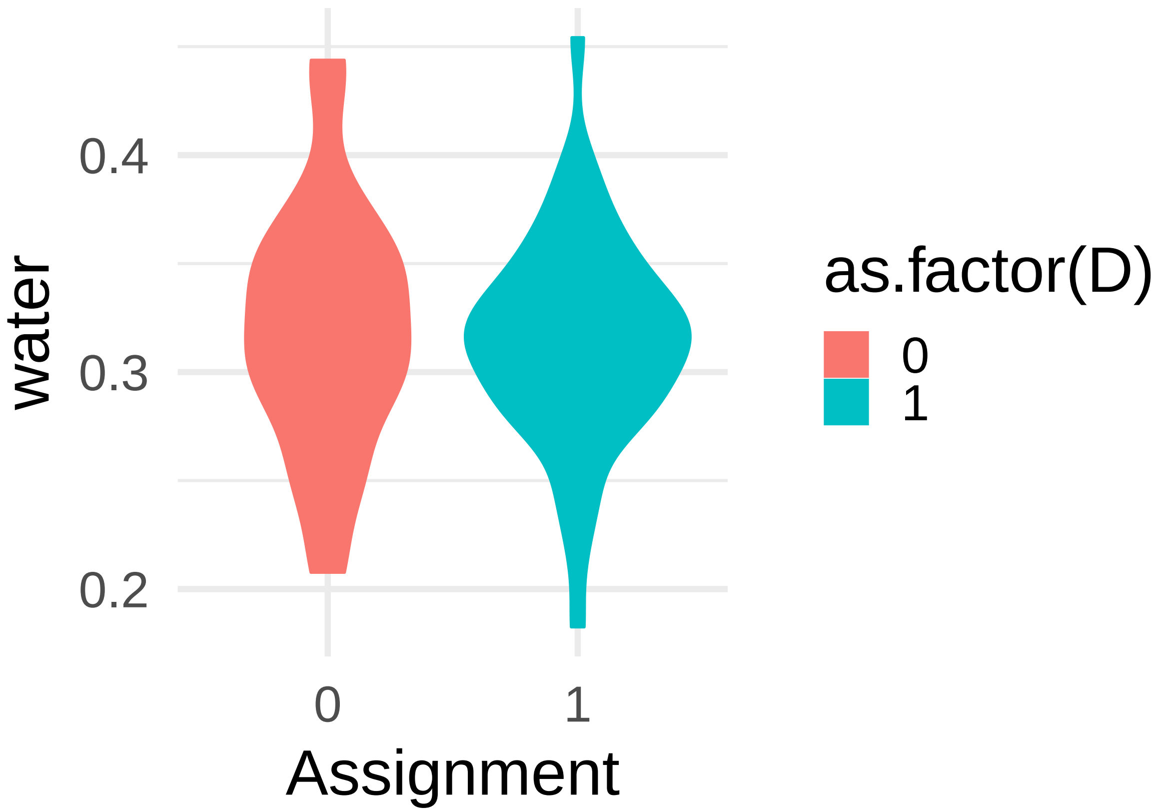
```
# sampling:
sampling <- declare_sampling(n=samp_size)
sam <- sampling(po)
kable(sam[1:5,c(1:2,4:6)], row.names = FALSE,
      digits = 1)
```

households	water	Y_D_0	Y_D_1	S_inclusion_prob
007	0.3	0.4	0.2	0.2
013	0.4	0.6	0.4	0.2
030	0.3	0.4	0.2	0.2
031	0.5	0.6	0.4	0.2
032	0.3	0.5	0.3	0.2

```
# random assignment to treatment:
assigning <- declare_assignment(prob = 0.5,
                  assignment_variable="D")
assigned <- assigning(sam)
kable(assigned[1:5,c(1:2,4:5,7:8)],
      digits = 1)
```

households	water	Y_D_0	Y_D_1	D	D_cond_prob
007	0.3	0.4	0.2	0	0.5
013	0.4	0.6	0.4	0	0.5
030	0.3	0.4	0.2	0	0.5
031	0.5	0.6	0.4	1	0.5
032	0.3	0.5	0.3	1	0.5

```
# check for variation in treatment vs. control groups:
ggplot(data=assigned, aes(x=as.factor(D), y=water)) +
geom_violin(aes(fill=as.factor(D), color=as.factor(D))) +
theme_minimal(base_size = 24) + xlab("Assignment")
```




```
# reveal and estimand:
revealing <- declare_reveal(assignment_variables=D)

estimand <- declare_estimand(ATE = te)
estimand(po)
```

```
##   estimand_label estimand
## 1            ATE   -0.157
```

```
# using the difference in difference test statistic:
did <- declare_estimator(Y - water ~ D,
                         estimand = estimand,
          model =  difference_in_means, label = "DID")


# finally declare design:
design <- population + potential_outcomes + sampling +
          assigning + revealing + estimand + did
```

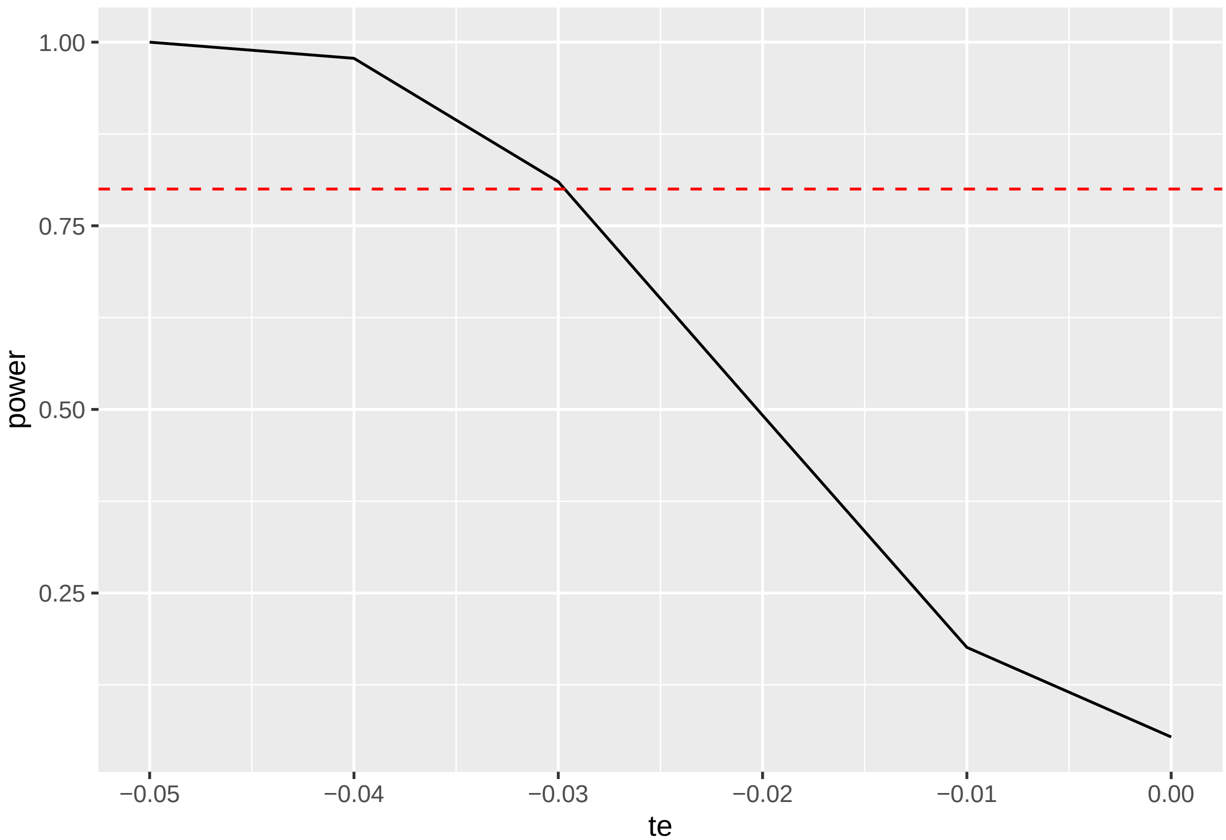
Minimum Treatment Effect

Find the minimum detectable effect for a set sample size of 330

```r
# select a range of possible te values
designs <- redesign(design, te=seq(from=-0.05, to=0, by=0.01))

diagnoses <- diagnose_design(designs, sims=500)

diagnoses$diagnosands_df %>%
  ggplot(aes(x=te,y=power)) +
  geom_line() +
  geom_hline(yintercept=0.8,
             linetype="dashed",
             color = "red")
```



From this plot it looks like with a power of 0.8 and a sample size of 100, the minimum detectable treatment effect is about -0.028 acre feet per household per year. This translates to approximately 9,124 gallons per household per year or an approximately 8.8% decrease in individual household water usage per year. Aggregated up to the 100 household participants this would equate to 2.8 acre feet of water per year. This is a rather low amount of water savings (less than one percent) relative to the county's average usage in 2016 of 730 acre feet per year.

If the effect was this low, we don't think the cost of the program would be worthwhile. However, the program claimed water savings were an order of magnitude higher than the minimum detectable treatment effect (0.157 acre feet per household or 50 acre feet total in 2016). This magnitude of change would be detected with high power under the current design.

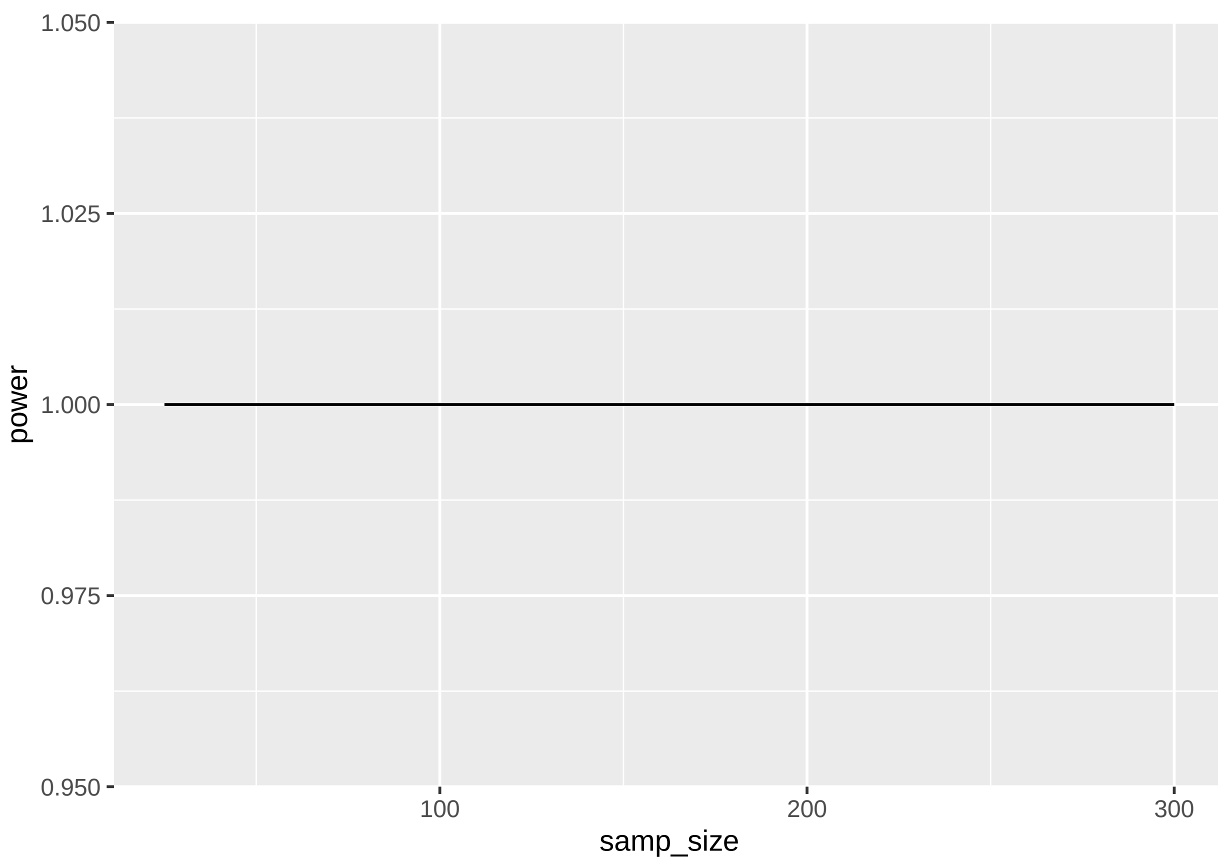
Minimum Sample Size

We wanted to determine the sample size needed to detect the level of change claimed by the 2016 program results (0.157 acre feet per year per household).

```
# select a range of possible sample sizes
designs_sam <- redesign(design, samp_size=seq(from=25, to=300, by=25))

diagnoses_sam <- diagnose_design(designs_sam, sims=500)

diagnoses_sam$diagnosands_df %>%
  ggplot(aes(x=samp_size,y=power)) +
  geom_line()
```



This plot seems to indicate that the treatmement effect would be detectable at any sample size from 25 to 300. This suggests that there may be some bias in the program of selecting households who respond better to treatment. This makes sense given the program allocates rebates on a first-come-first-serve basis for ethical reasons.

In 2016, the program claimed to reduce water use by 50 acre feet per year, based on replacement of 357,000 square feet of turf across the 330 participant homes. If we assume water usage and turf replacement occurred evenly over all 330 homes, this amounts to replacing about 1,082 square feet of turf at every home and saving approximately 140 gallons of water per day.

On average, turf in residential homes on the inner coast require 0.25 acre feet of water annually or about 223 gallons per day, based on the average turf size of 7,390 square feet per household PPIC 2006. Using this data, we would expect a reduction of 1,082 square feet of turf to save approximately 31 gallons of water per day (or 0.035 acre feet per year).

This value seems to fall between the minimum detectable treatment effect and the claimed 2016 program effect (-0.028 and -0.157 acre feet per household per year, respectively). The impact evaluation may need to evaluate a stronger program that has at least a treatment effect of 0.035 acre feet per household per year of water savings. While any amount of water savings among residents is a step in the right direction, there may be a more cost-effective way for the City to reach their water conservation targets.