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Causal Inference on Bananas

INTRODUCTION:

It is folk wisdom that to prolong the ripening, or ‘browning’ or bananas, one can wrap their stems in aluminum foil. However, is this statement fact or fiction?

I intend to test the impact of covering the stem of an individual banana in aluminum foil on how fast it takes for a banana to completely ripen. My units will be 30 bananas, bought from Shop-and-Stop. All of the bananas looked roughly identical in terms of ripeness, roughly yellow-greenish.

My analysis included randomization inference and t-test to determine whether there is statistically significant evidence to claim that the true average treatment effect (ATE) > 0 between the treatment and control groups, a power calculation to determine the probability of detecting a statistically significant result of my original design, and an OLS analysis with other covariates I measured, including whether the banana had a ‘Chiquita’ sticker on it and the height of a banana to discover other features that may contribute to ripening time.

Ultimately, I did not find a statistically significant result, meaning that my design did not yield evidence that covering the stems of bananas in aluminum foil increases a banana’s ripening time. My difference in means estimator was -0.6, meaning that from my sole data, bananas in the control group ripened at a slower pace than those in the treatment group.

FIGURE A: My bananas at the end of the experiment- one covered in foil and one that was not covered in foil.

THEORY:

The primary hypothesis that I will be testing is whether the following null hypothesis is true:

H0: there is no difference between the time it takes for bananas not covered in aluminum foil to ripen completely

H1: it takes more time for bananas covered in aluminum foil to ripen completely.

In Difference-In-Means terms, Let Yi(1) be the number of days until a banana fully ripens under the aluminum foil treatment, and Yi(0) be the number of days until a banana fully ripens under control. I am interested in testing whether $E[Yi(1) - Yi(0)] = 0$ as my null hypothesis and $E[Yi(1)−Yi(0)]>0$ as my alternative hypothesis.

I am testing against a 1-sided alternative hypothesis because the aforementioned 'conventional wisdom' gives me reason to believe that aluminum foil does make the ripening process slower. I'm assuming that each banana's ripening period is independent of each other's. In other words, for each treatment group, one banana's ripening time will not affect another banana. I plan on conducting randomization inference on the Sharp Null Hypothesis of No Effect. I will follow this procedure:

- My null hypothesis will be H0: Yi(1) - Yi(0) = 0
- Using my test statistic as difference in means, I will compute it on my dataset (my results was -0.6, which Yi(1) = 13.6666 and Yi(0) = 14.266)
- Set Yi(0) = Yi(1) for all 30 bananas
- Run 10,000 random assignments of 15 of the bananas to treatment and 15 of the bananas for control. For each of these assignments, calculate the difference-in-means between the treatment and control groups in each assignment.
- To compute a p-value, calculate p =(#T-statistics >= - 0.6)/10000

Then, I will corroborate my findings with a t-test for difference in sample means between the days. Using the t-test function in R, I will conduct a two-sample t-test. The default of the t-test is Welch's t-test, which assumes unequal variances. This is a valid assumption because I do not have reason to believe that ripening times for bananas covered in aluminum foil versus bananas not covered in aluminum foil have the same spread. I plan to generate a 95% confidence interval for difference in means and conduct the test at the 0.05 significance level.

Finally, I decided to conduct an OLS analysis through creating a linear model with covariates (list linear model), which will be as follows:

Yi = A + BDi + Cx1i + Ex2i,

Where Yi represents the ripening time for a banana, A represents an intercept term, B represents the slope for Di, which is the treatment(1 for treatment, 0 for non-treated), C represents the slope for x1i, which is the height of a banana (in inches), and E, which is the slope for x2i, which is a binary variable that describes whether the banana had a sticker on it. The motivation of using OLS is to determine how much of an effect all of the variables have on the ripening time on the banana. Specifically, I decided to test the height of a banana because if ripening occurs uniformly across surface area, then it would make sense for larger bananas to ripen slower. Furthermore, stickers represent another material that covers an area of a banana- plastic. In this way, my analysis of the stickers binary covariate serves to determine if plastic influences the ripening time of a banana, similar to my causal experiment of whether aluminum influences bananas. I did not include any interaction effects in my model because I did not have a reason to believe in any interaction effect between the variables.

DESIGN:

I will have two treatments- one being the control(bananas with uncovered stems), and one being the treated group of bananas that have stems that are covered in aluminum foil.

Using complete random assignment, I specified to have 15 in the control and 15 in the treatment group. My random assignment procedure will be writing down numbers 0 and 1 on 15 slips of paper each, putting them in a box, and without looking, for each banana, take out a slip of paper, where 0 corresponds to the control group and 1 corresponds to the treated group.

To measure the outcome, I will count the number of days it takes for a banana to turn brown. I plan to start the experiment at 9 AM, and will observe the bananas every day at 9 AM and observe if they are brown. I will then count the number of days it took for me to observe that the bananas have turned fully brown since April 8, which is when I started the experiment.

Figure B: I consider the leftmost banana to be 'fully ripened.'

Through this design, I've made sure that the three criteria for causal inference are satisfied. First, random assignment of the treatment took place, as specified above. To ensure excludability, I controlled for the relative location of all bananas- to be placed on an empty bed in the same room. As I read that temperature affects banana ripening, by ensuring that bananas are in the same place, the temperature of each banana's environment should be the same. Another factor I considered was ensuring that the distance of bananas would be roughly equal to one another. Hence, I attempted to ensure 0.5 inches between each banana. Finally, I ensured non-interference by ensuring that distances between bananas were equivalent and by ensuring that aluminum foil covering one banana did not touch another banana. Hence, one banana's treatment assignment would not affect another.

For additional measurements for the height of the banana and the sticker, there was no random assignment, so importantly, I cannot assume causality. However, to measure the height of the bananas, I solely measured a banana's vertical height. This is not necessarily a completely accurate representation of the banana's size because bananas that are short can be curved heavily, and still be larger than bananas that might be slightly taller and are curved less. However, measuring curvature would be extremely difficult, and the weight of bananas were too minimal for my scales to detect a difference in their weight. The heights of the bananas were measured after each banana finished ripening. Hence, I do believe that my measurement of height does still account for a measurement of the banana's size. Regarding stickers, 12 of the 30 bananas I bought had a sticker.

I also performed a power calculation using DeclareDesign. By calculating the power, I hope to determine the probability of observing a statistically significant result for even a small true effect size(1 day) at the alpha = 0.05 level. For N=30, assuming that the treatment and control groups are normally distributed, with the treatment centered at mean = 16 and the control centered at mean = 15, my power is 0.74, which I am satisfied with.

To increase precision, I considered blocking by banana bunch in my proposal to account for variation in how ripe the bananas were before the start of the experiment. However, in each bunch of bananas I bought, the bananas themselves varied greatly in terms of their ripeness. Oftentimes, bananas of different bunches would be of more similar ripeness than bananas of the same bunches. Therefore, blocking would not be a reflection of the reality of the ripe status of bananas.

RESULTS

First, I will present the spread of my data through histograms of the control and treatment group.

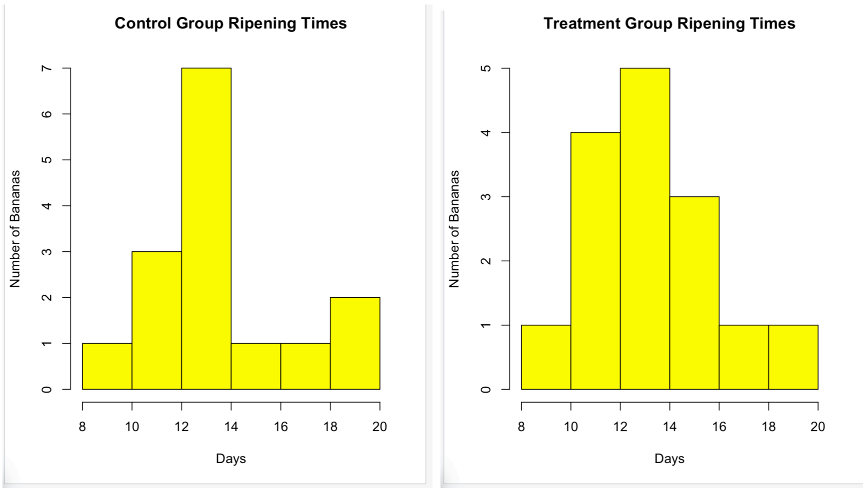

Figure 1: Histograms of Control Group and Treatment Group Ripening Times, Scatterplot of Data on the Right

Both histograms are relatively normally distributed, with the control group being slightly skewed right. The mean ripening time for bananas in the treatment group is 13.6666 days, while the mean ripening time for bananas in the control group is 14.2666 days. Focusing on my estimator for the ATE, my difference in means(Yi(1)- Yi(0)) is -0.6. However, when using the t.test function in R to construct 95 percent confident confidence intervals, there exists overlap between the intervals of both the control and the treatment group(refer to Figure 3).

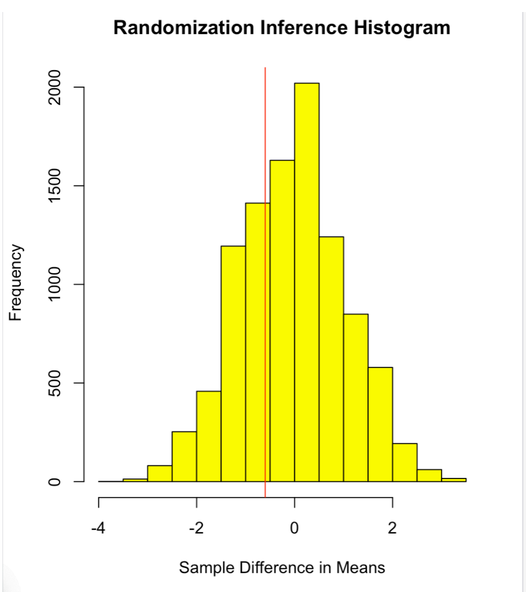

Figure 2: Histogram of my 10000 simulations from randomization inference. The red line represents the difference-in-means, which is -0.6.

Through conducting randomization inference, my calculated p-value is 0.71, meaning that under any common significance level(i.e. 0.05, 0.10, 0.01), I would not have statistically significant evidence to reject the null hypothesis that there is no difference in means between the treatment and control group.

My t-test reveals similar results: my calculated p-value is 0.57, meaning that under any common significance level, I would not have statistically significant evidence to reject the null hypothesis that there is no difference in means between the treatment and control group. At the 95 percent confidence level, my computed confidence interval for the difference in means is (-2.75, 1.55), meaning if I were to repeat my experiment many times, 95% of the calculated intervals would contain the true population parameter. Because 0 is within this confidence interval, I do not have evidence to reject the null hypothesis.

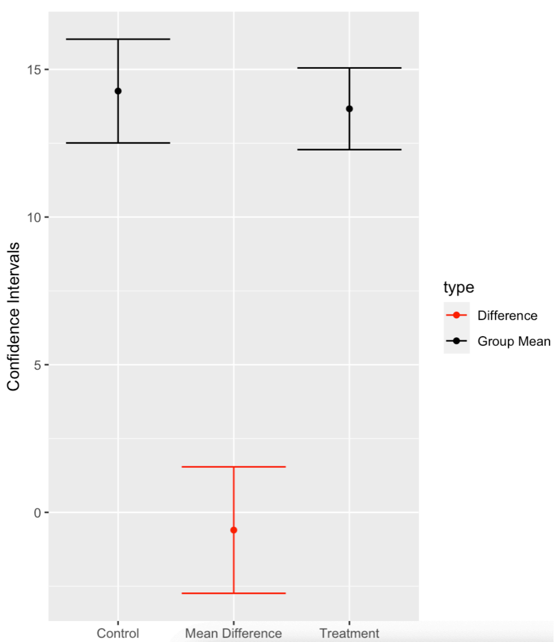

Figure 3: Using R's t.test function, 95 percent confidence intervals for control group, treatment, and difference in means.

My OLS analysis found a coefficient of -0.65 for my treatment, 1.04 for whether or not bananas had a sticker, and -1.05 for height. To interpret these, applying the treatment condition to a banana is estimated to reduce its ripening time by 0.65 days, bananas that have a sticker tend to take 1.04 more days to ripen, and for every inch of a banana's height, their ripening time is projected to reduce by 1.05 days. However, it is important to note that the p-values for all of these factors are larger than any common significance level used (0.05, 0.10, 0.01), meaning that they are not statistically significant predictors of ripening time. As the covariates were not statistically significant, I also found no reason in using CATEs, conditioning on these covariates.

	term	estimate	std.error	p.value	conf.low	conf.high
1	(Intercept)	20.9737611	5.7836436	0.001228698	9.085312	32.8622107
2	D	-0.6491854	1.0320360	0.534815217	-2.770566	1.4721951
3	Sticker	1.0444112	1.0181811	0.314453254	-1.048490	3.1373125
4	Height	-1.0539732	0.8543305	0.228357498	-2.810075	0.7021283

Figure 4: OLS Table

DISCUSSION:

Ultimately, through randomization inference, t-test, and OLS, my analysis and data do not posit evidence to reject the null hypothesis that there is no difference between bananas covered with aluminum foil versus bananas that are not covered in aluminum foil, testing against a one-sided null hypothesis. With my difference-in-means estimator of my experiment being -0.6, meaning that bananas in my experiment that were covered in aluminum foil actually ended up ripening, on average, 0.6 days faster. Hence, it makes sense that I did not have statistically significant evidence to reject the null hypothesis.

There are several issues that could have influenced this result. First, because of how I measured time - in days- it is possible that there would be more variation in time it took for a banana to ripen. As several of my bananas ripened on the same day(e.g. a lot of bananas, regardless of treatment, ripened on days 12 and 14) even though one banana may have finished ripening much sooner than another by a few hours, my data collection does not emphasize this difference.

Second, my measurement for counting a banana as ‘fully ripened’ could have been more precise. For certain bananas, over ninety-percent of the banana’s body would become fully ripened, but there existed a small spot in the banana that was still unripe. I would not count the banana as fully ripened until all noticeable spots are completely ripened. This means that my method of calculating the rate of ripening might not necessarily tell the full picture of aluminum foil’s impact on the ripening of bananas. For instance, consider a banana that ripens very quickly, but one spot on the banana ends up not ripening for several days, versus another banana that ripens at a uniform but slow pace, where both bananas end up fully ripened at the same day. While, for practical and banana-eating purposes, there would be a difference between the two banana’s ripening times, my data reporting method would state that these two ripen at the same rate.

Ultimately, my experiment demonstrates that through my estimator of the difference in means of the ripening time of bananas with stems covered in aluminum foil versus bananas with stems not covered difference in means suggests that even controlling for covariates, there exists no evidence tos support folk wisdom that aluminum foil increases banana ripening time.