Going Green – With Envy

W241 - Experiments and Causality

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1 Executive Summary

The recycling rate of US is only 35%, ranking #25 in the world. The basic research question for our experiment was to find if we can improve recycling in the US by means of social comparison. The experiment was conducted in two neighborhoods in Montgomery County, MD whose recycling rates are low. Our target population were "non-recyclers" - those who are not currently participating in recycling and treated them with a flyer which would compare their neighborhood's recycling rates to the county's overall recycling rate. We chose a simple measurement - recycling participation rate for this project and the estimated effect from the sample data is -0.1 which is contrary to our expectation. However, this effect is not significant. For future experiments, we could treat our subjects repeatedly and measure the outcome variable longer for both pre-treatment and post-treatment. Further, we need to increase the sample size to increase the power.

2 Introduction

We live in a world We live in a world where human population has grown over the years as a result of improving life-expectancy and currently stands at 7.6 Billion. Addition of every single human being to the planet adds significant waste over his or her lifetime and in New York alone, an entire Empire State building can be filled with just one day of trash collection. With the steady increase in population and the prevalence of certain societal factors like increase in wealth leading to more buying, development of new packaging and technical products that are not biodegradable and lifestyle changes over reliance of fast food consumption all leading to more and more waste being created in the world.

By 2100[1], the increasing global urban population will be producing three times as much waste at it does today. If the world keeps up with the current urbanization and population growth rate, the global waste generation is estimated to rise to 2.2 billion tons by 2025[2]. All this waste being produced has been having a grave and negative impact on the environment.
1. Generation of harmful chemical and greenhouse gases from landfill sites.
2. Effects of deforestation to habitat destruction and global warming.

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[1] http://www.worldbank.org/en/news/feature/2013/10/30/global-waste-on-pace-to-triple
[2] http://www.globalwastemanagementconference.com/

3. Larger amounts of energy required to build new products from raw materials.

One way to combat the issue of increasing waste is through recycling - *the process of collecting and processing materials that would otherwise be thrown away as trash and turning them into new products.* In addition to benefiting the economy (according to 2016 Recycling Information Report[3], it was estimated that in 2007, activities related to recycling in US contributed to 757,000 jobs, $36.6 billion in wages and $6.7 billion in tax revenue), recycling impacts our environment positively by:

1. Reducing waste sent to landfills
2. Conservation of natural resources (wood, water, minerals), pollution by reducing the need for creation of new materials.
3. Savings in energy consumption by reusing existing products vs. building new ones.

Clearly recycling is a great way to arrest the negative impact to the environment resulting from increased consumption due to ever increasing population.

But not everyone recycles. According to a recent report[4] Germany ranks #1 on the list of countries with the highest recycling rate with 65% of its waste being recycled; The United States of America ranks #25 on that list with an overall recycling rate of 35%. How can we do better in the US?

2.1 Social Comparison Theory

In Psychology, motivation for individual action[5] has been well-studied. One way to motivate people is through Social Comparison Theory[6] - a theory first proposed by Leon Festinger, which states that we determine our personal worth based on how we stack up against others. Our experiment is predicated on motivating individuals to act for social-good using Social comparison.

3 Experimental Design

In this field experiment study, we intend to estimate the effect of social comparison on recycling. Many municipalities spend a lot of resources educating their residents on the benefits of recycling. In Montgomery County, MD (our test geography), there is an annual flyer that is mailed to every resident of the county informing them of the benefits of recycling and providing information on how and what to recycle. According to Alan Pultyniewicz the recycling

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[3] https://www.epa.gov/sites/production/files/2017-05/documents/final_2016_rei_report.pdf
[4] https://www.weforum.org/agenda/2017/12/germany-recycles-more-than-any-other-country/
[5] https://www.psychologytoday.com/us/articles/201701/the-mystery-motivation
[6] https://www.psychologytoday.com/us/basics/social-comparison-theory

coordinator for Montgomery County (MoCo), MD – current recycling rate [7]in MoCo is 61% with a goal of getting to 70% by 2020. While the county has engaged in a lot of education efforts to increase recycling (print ads, billboards, social media) , they don't really have a good handle on the impact of these individual efforts. Participation rates vary by neighborhoods and in general there seem to be an economic divide with higher-income neighborhoods with higher participation (rate at which recycling material is put-out for pick up) than lower-income neighborhoods.

The field experiment in this study is an attempt to measure the impact of direct-communication (mail-in flyer) on recycling participation when the mailer includes a social comparison tactic.

3.1 Outcome Measure

Montgomery County has a data-based approach to their recycling program. As a result, they collect recycling data daily for each pick-up route (a pick-up route typically consists of 400-600 residential units). Ideally, we would have been able to use this data for our experiment, however, there are some challenges with the way the data is collected, stored and is made available by the county that required us to take a different approach for this experiment.
To fit the experiment to the resources available for this project, we decided to focus on a different outcome measure – "recycling participation" – essentially an indicator (1 or 0) for whether a household made recycling materials available for pick-up on the scheduled collection day for the neighborhood.

3.2 Target Population

Given that the recycling rate is already very high (61%) in MoCo, in order use resources more efficiently, it makes sense to target future efforts at increasing recycling rates to residents that are not currently participating in the recycling effort. So our target population is MoCo residents that are not currently participating in the recycle program.
Given the limitations of time and resources available for this field experiment project, we decided to collect a small sample of single family residents in MoCo that are non-participants in

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[7] https://www.montgomerycountymd.gov/sws/

the recycling program. We did this by studying recycling patterns near one of the researcher's home (a rather convenient sample), for several days and decided on a subset of two routes (RE13W02 and RE13H02) that had enough non-participating residents based on one set of observations. There were 186 houses in these two routes (out of a total of 485 houses observed) that did not participate in the recycling program in the pre-treatment period.

3.3 Experiment Duration

We took one pre-treatment measurement of the outcome to help identify the sample of the target population we will be conducting our experiment on. Once we randomly assigned our treatment (details below), we administered our treatment – which was a direct-mailed postcard (details below) with information about the extent of participation in the neighborhood compared to overall county statistics, along with other useful information on how and what to recycle. We measured the outcomes one week after treatment. The timing of the measurements in shown in the table below:

03/08/2014	03/14/2018	03/25/2018	04/04/2018	04/05/2018
Pre-treatment	Pre-Treatment	Treatment	Post-Treatment	Post-Treatment

3.4 Treatment

The flyer includes benefits of recycling to the environment, and how you can recycle in Montgomery County through pictures on the front page. It has social comparison data on the back, encouraging the treated neighborhood to recycle more to achieve the average recycling rate of the county and meet the county's goal.
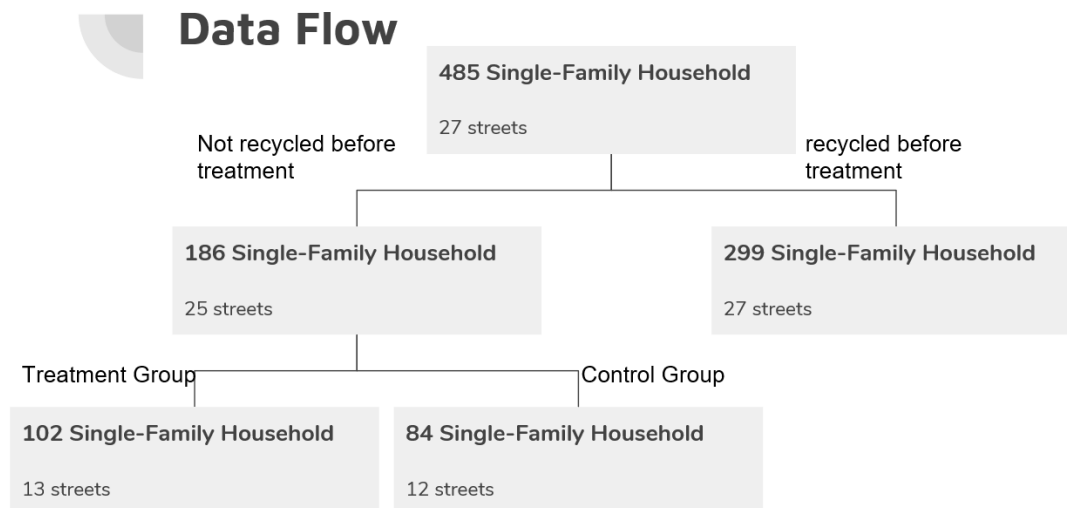
As recycling rules vary by county or state, we used the information from the county's website and integrated all the information into the flyer with one style. While we designed the treatment to be as effective as possible (catchy colors, large font, post-card vs. envelop) to increase compliance (i.e. read the flyer), we realize that not all the houses assigned to treatment might have complied with our treatment. Ideally, we would have done a follow-up survey to identify the households that were assigned to treatment – to get a measure of whether they were actually "treated" i.e. read the postcard we sent them. Since we did not pursue the follow-up survey approach, our estimated treatment effect is an "intent to treat" measure and not the actual treatment effect. Since we do not have an estimate for the compliance rate, we cannot compute a Complier Average Causal Effect for the treatment either.

We've printed different sizes of postcard, namely, 7"x5", 8.5"x5.5" and 11"x8.5" and picked the medium size which is a good size for postcard and also readable. To stress recycling concept, we use recycled-like paper for all postcards.

3.5 Clustered Random Assignment

Since neighbors may talk to each other (and observe each others' actions) - it is possible that there might be some treatment spill-over if we assign houses in a neighborhood to different treatment conditions. Therefore, we conducted random assignment at street level - an entire

street gets the same treatment condition. There are 25 streets in our sample, and we randomly assigned 13 of them to treatment group – (out of the 186 households selected for this experiment, there were 102 households assigned to treatment and 84 assigned to control). Please see the data flow chart below.

Data Flow

485 Single-Family Household

27 streets

Not recycled before treatment

recycled before treatment

186 Single-Family Household

25 streets

299 Single-Family Household

27 streets

Treatment Group

Control Group

102 Single-Family Household

13 streets

84 Single-Family Household

12 streets

4 Covariates

There are several factors that could influence someone's recycling behavior – belief that it matters, environmental awareness, social mores/peer-pressure, income, education level etc. Because of our experimental design (randomized control trial), these covariates are independent from the treatment assignment – therefore our treatment-estimates are unbiased. However, we might be able to get better precision on our treatment-estimate by using some of these covariates if they help explain some of the variance in the outcome measure. In reality, getting household level information for the metrics listed above is either unmeasurable or just difficult to obtain for this project. Instead, we used route number and calculated neighbor score in our analysis.

5 Data Collection

The outcome we were interested in is recycle participation i.e. did a household put out recycle materials for pick up or not. In order to select our target population (those that are currently non-participants), we did a pre-treatment measurement. We scouted several routes before deciding on two that had enough non-participants to execute our experiment.

To ensure that we had the most accurate participation data, we had to time the data collection right before the regular pick-up times. The actual data collection was done through a video recording using a GoPro camera mounted on a car-window and driving along the collection route. Our preliminary scouting runs helped us fine-tune this data collection method - and we ended up with a combination of video recording as well as audio recording where the researcher read out the house number and the bin-status as they drove along the recycle route.

This experiment study uses double blindness. First, the subjects did not know that they were participating in the experiment. Second, the researcher who collected the data (both pre-treatment and post-treatment) was not made aware of the treatment assignment which was conducted by a different researcher.

6 Analysis and Results

6.1 Exploratory Analysis

Below exploratory charts are for the 186 houses in the experiment. Most streets have less than 20 houses per street, though we have one outlier with 40 houses "Potomac Oaks Drive". There are more houses on route "RE13W02" where recycling bins are picked up on each Wednesday and bins are picked up on each Thursday for route "RE13H02". Overall, there are 36% of households put their recycle bins for pickup during the week post treatment.
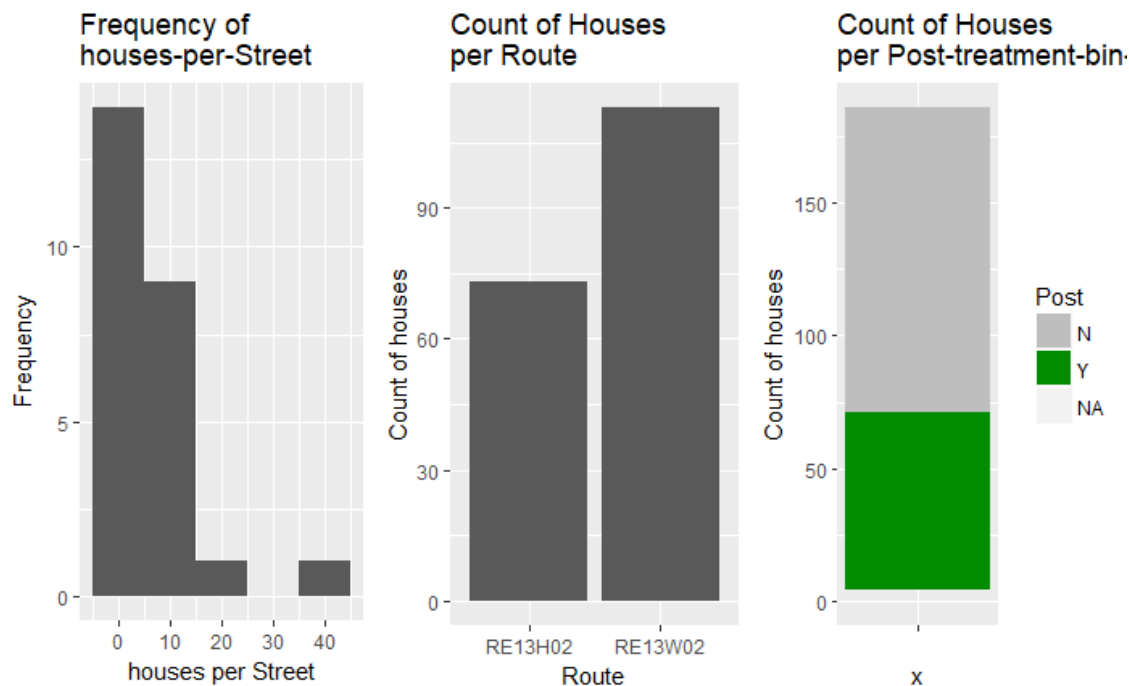
Neighbors' score is a ratio of houses with bins to the number of neighbors for each house (neighbor defined as 0 > distance < 60 meters). We see that our houses on average tend to be with neighbors that are rather favorable to recycling (median ratio is 0.6). The median score of the control group is higher than the treatment group. We will next check whether the difference is by chance.
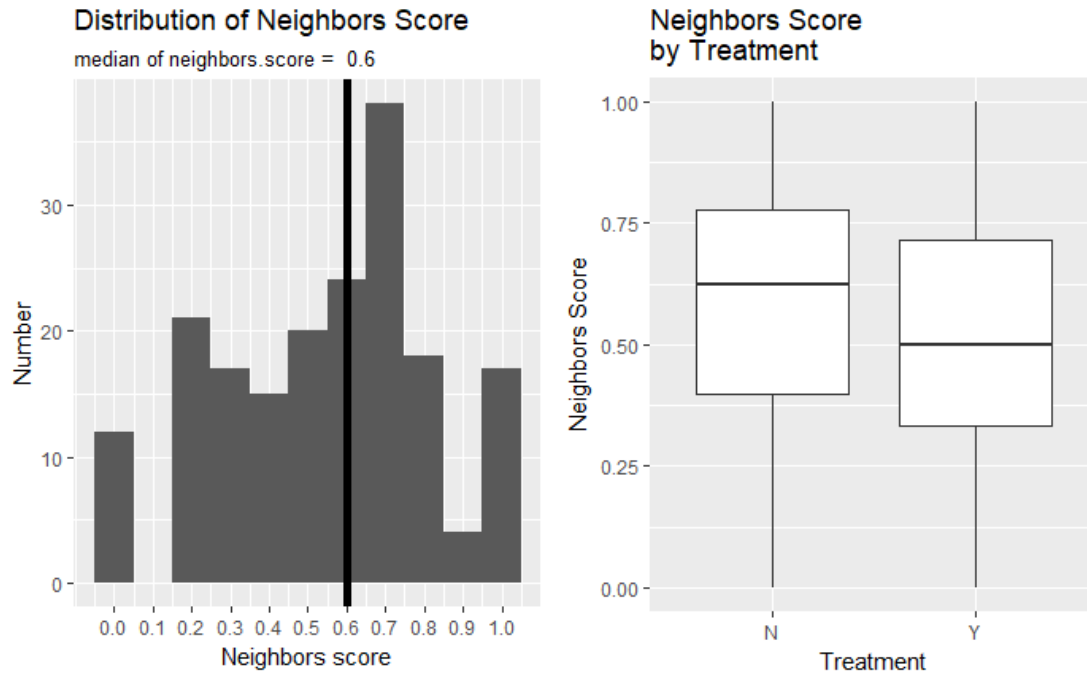
Variable Definition:

Field	Comments
Street	Houses' street, our cluster variable
Number, City, State, Zip	Houses' address, city, state, and zip code
Route, PickupDOW	Route ID and Pick-up Day of Week, either Wed or Thurs
Pre	Y/N indicator for whether we saw a bin before treatment
Post	Y/N indicator for whether we saw a bin after treatment
Treat	Y/N indicator for whether the house was assigned to treatment or control
Street Score	Ratio of number of Pre=Y, to number of houses on the street, for each street
Neighbors Score	Ratio of number of Pre=Y, to the number of neighbors, for each house (neighbor defined as 0 > distance < 60 meters)

6.2 Covariate Balance Check

We compared a short and long model to check if our randomization work. We got a low p-value of 0.0001897 from the ANOVA test, indicating that our covariates actually predicts our treatment group.
Unfortunately, it looks like we didn't quite split our assignment to treatment and control fairly with regards to these covariates. But that is explainable, because our design randomized by street, and did not actively balance across covariates of neighbors score or street score.

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Analysis of Variance Table

Model 1: D ~ 1
Model 2: D ~ 1 + street.score + neighbors.score + wed
 Res.Df    RSS Df Sum of Sq  Pr(>Chi)
1    185 46.065
2    182 41.552  3    4.5128 0.0001897 ***
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6.3 Treatment Effect

We used regression to estimate treatment effect. "Post.bin" is our outcome variable, which is the likelihood a house will put out a bin (0 to 1). The basic short model showed a non-statistically significant negative potential outcome to treatment of -0.101, with a confidence interval of (`-0.2436059 0.04066474`), crossing 0. The intercept in the short model means that potential outcome to control is 42% likelihood to put out a bin. The basic long model showed a non-statistically significant positive potential outcome to treatment of -0.065, with a confidence interval of (`-0.20819741 0.07750162`), crossing 0.

Therefore, we did not find any statistically significant results for our Treatment and we cannot reject our null hypothesis that our treatment had no effect.

Estimated Model Parameters:

| N = 182	Short	Long
Treatment	−0.101 (0.095)	−0.065 (0.070)
Neighbors Score		0.094 (0.213)
Pickup (Wed)		0.185*** (0.071)
Constant	0.425*** (0.070)	0.242** (0.118)
R2	0.011	0.05

 *p<0.1; **p<0.05; ***p<0.01

6.4 Missing Data

There were 5 missing records due to measurement errors and we performed boundary analysis for the missing data. If we assume they all would NOT have put out a bin, using the long model the treatment effect would have been -0.044 (0.076). If we assumed they would have put out a bin, using the long model, the treatment effect would have been -0.089 (0.068). Neither were statistically significant.

6.5 Power Analysis

As we do not have knowledge of the expected effect size or the variability of outcome, we performed post-hoc power analysis for further experiment. Using sample means of control group and treatment group and effect size (-0.1), we simulated the experiment 1000 times and found our power is only 27.4%. To achieve 80% power with the same effect size, we need to increase sample size from current 186 to 730.
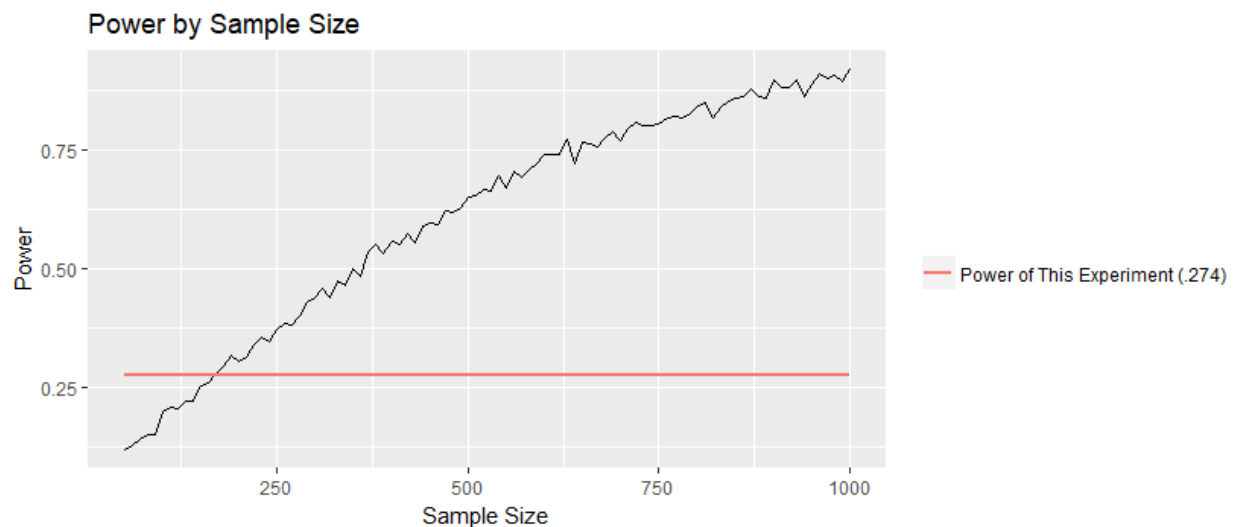
7 Conclusions

From this sample data we detected -0.1 effect size but it's not significant at 5% level. However, with only 186 subjects, the power is only 27.4% to detect this effect size. Therefore, there is no evidence showing that we changed people's recycling behavior using one-time treatment.

7.1 Limitations and Future Opportunities

We all know that it's difficult to change people's behavior and form a new habit, such as recycling. Ideally, we would treat our subjects several times, such as quarterly or even monthly to keep reminding people of the benefits of recycling and measure the outcome variables for a longer period of time after the treatment is over to detect the long-term effect. Due to limited resources and time, we only have one-time treatment and measure the short-term effect in this course project.

Another limitation of this study is that we use participation rate instead of more accurate outcome measurements, such as recycling rate = recycled material weight divided by the weight of trash and recycled material due to difficulty of measure or collect data regarding the weight of trash.