Multiple Approaches to Causal Modeling Using Black Spruce Data

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# Background 🌲

Chihara and Hesterberg (2018) provide a data set concerning the growth of Black Spruce Trees. According to these authors:

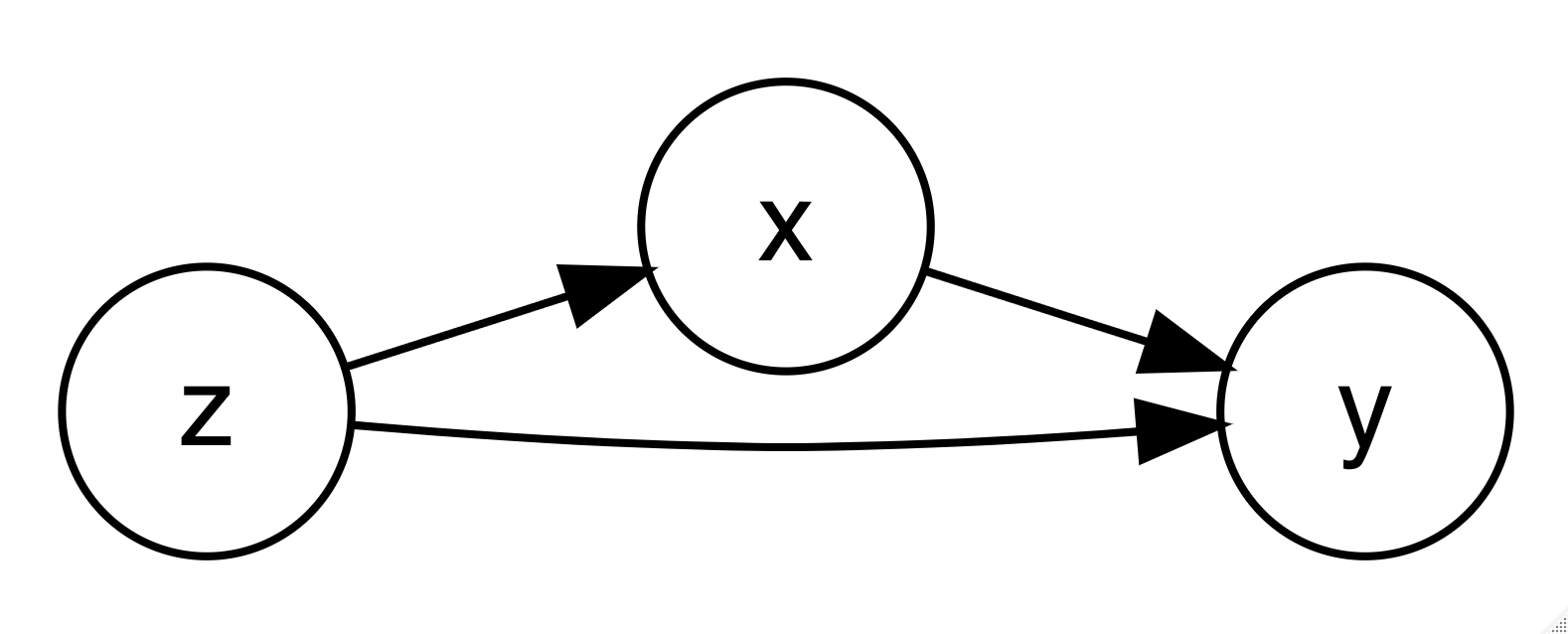
“Black spruce (Picea mariana) is a species of a slow-growing coniferous tree found across the northern part of North America. It is commonly found on wet organic soils. In a study conducted in the 1990s, a biologist interested in factors affecting the growth of the black spruce planted its seedlings on sites located in boreal peatlands in northern Manitoba, Canada (Camil et al. (2010)). The data set Spruce contains a part of the data from the study (Table 1.8). Seventy-two black spruce seedlings were planted in four plots under varying conditions (fertilizer–no fertilizer, competition–no competition), and their heights and diameters were measured over the course of 5 years. The researcher wanted to see whether the addition of fertilizer or the removal of competition from other plants (by weeding) affected the growth of these seedlings.”

# The Research Question 🌲

We are going to consider the *potentially causal* estimate of the effect of *fertilizer* on *tree height at year 5*. Along the way we will give brief attention to the advantages and disadvantages of each approach. Because of the research design, we have strong reasons to consider *fertilizer* as having a causal effect on *tree height* but we will nonetheless explore this question using a variety of statistical models.

A secondary purpose of this document is to demonstrate that Stata syntax makes it easy to test and compare multiple statistical models because of the uniform Stata syntax, which is almost always: command variable(s), options.

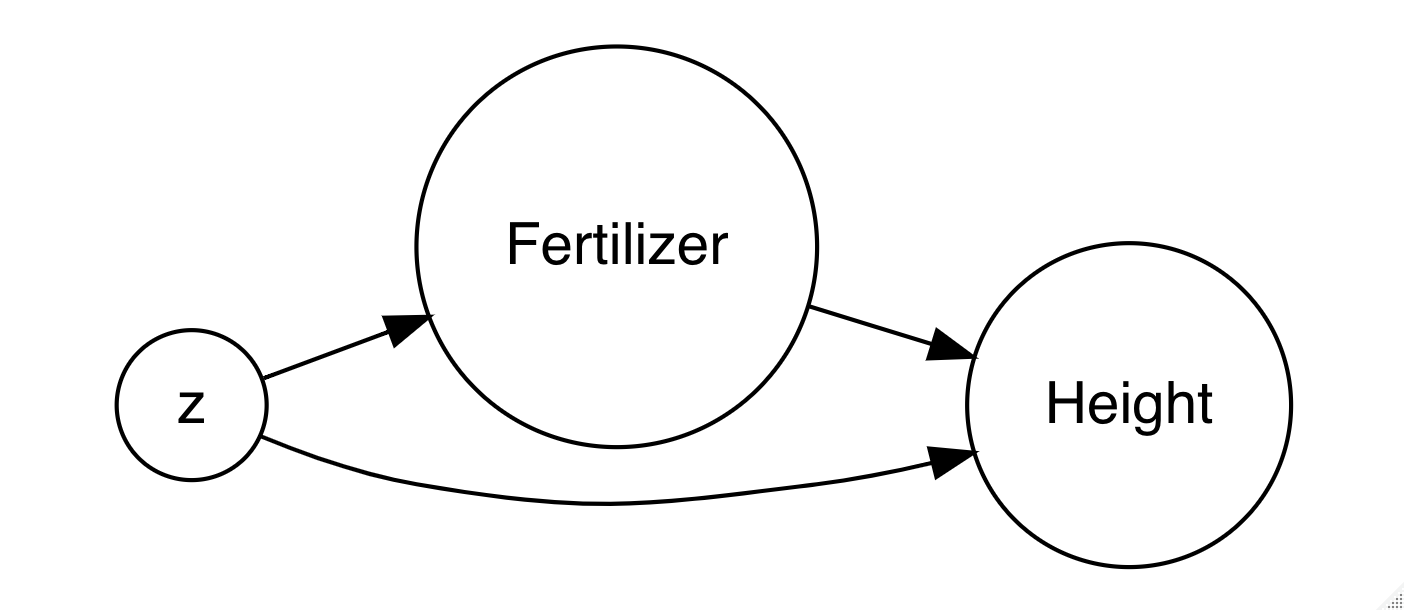
# Causality 🌲



A variable can only be considered to have *causal* association with if the following conditions are met (Holland, 1986):

1. is correlated with .
2. precedes in time order.
3. The association between and can not be accounted for by any third variable .

Hence, for this particular data, we are exploring:



What happens to the association of *fertilizer* and *tree height* when we control for possible confounding variables using various statistical strategies?

(For more interactive exploration of these ideas, see [this demo](https://agrogan.shinyapps.io/causality/)).

# Setup 🌲

## Get Data

. clear all  
  
. quietly: cd "/Users/agrogan/Desktop/newstuff/spruce"  
  
. use spruce.dta, clear

## Dataset Description

. describe   
  
Contains data from spruce.dta  
 obs: 72   
 vars: 9 26 Apr 2020 12:18  
 size: 4,320   
─────────────────────────────────────────────────────────────────────────────────────────────  
 storage display value  
variable name type format label variable label  
─────────────────────────────────────────────────────────────────────────────────────────────  
Tree long %12.0g Tree number  
Competition long %12.0g Competition  
 C (competition), CR (competition removed)  
Fertilizer long %12.0g Fertilizer  
 F (fertilized), NF (not fertilized)  
Height0 double %10.0g Height (cm) of seedling at planting  
Height5 double %10.0g Height (cm) of seedling at year 5  
Diameter0 double %10.0g Diameter (cm) of seedling at planting  
Diameter5 double %10.0g Diameter (cm) of seedling at year 5  
Ht\_change double %10.0g Change (cm) in height  
Di\_change double %10.0g Change (cm) in diameter  
─────────────────────────────────────────────────────────────────────────────────────────────  
Sorted by:

# Analyses 🌲

## t Test

A t test compares the difference between the means of two groups to the standard error of the difference between means.

Formally, where s is the standard error of the estimate of the mean.

More colloquially, the t test compares the differences between the two groups in standard error units.

A t test does *not* control for any additional variable(s).

. ttest Height5, by(Fertilizer)  
  
Two-sample t test with equal variances  
─────────┬────────────────────────────────────────────────────────────────────  
Variable │ Obs Mean Std. Err. Std. Dev. [95% Conf. Interval]  
─────────┼────────────────────────────────────────────────────────────────────  
 F │ 36 52.89167 1.396079 8.376476 50.05747 55.72586  
 NF │ 36 38.11944 1.465226 8.791354 35.14488 41.09401  
─────────┼────────────────────────────────────────────────────────────────────  
combined │ 72 45.50556 1.333392 11.31421 42.84685 48.16426  
─────────┼────────────────────────────────────────────────────────────────────  
 diff │ 14.77222 2.023839 10.7358 18.80864  
─────────┴────────────────────────────────────────────────────────────────────  
 diff = mean(F) - mean(NF) t = 7.2991  
Ho: diff = 0 degrees of freedom = 70  
  
 Ha: diff < 0 Ha: diff != 0 Ha: diff > 0  
 Pr(T < t) = 1.0000 Pr(|T| > |t|) = 0.0000 Pr(T > t) = 0.0000

The association of fertilizer with tree height is -14.77.

## OLS Regression

A regression estimates the association of a 1 unit change in each of the independent variables with change in the dependent variable, while accounting for all of the other independent variables in the model.

A regression controls for the additional observed variables that are included in the model.

. regress Height5 Fertilizer Height0 Competition  
  
 Source │ SS df MS Number of obs = 72  
─────────────┼────────────────────────────────── F(3, 68) = 50.97  
 Model │ 6291.23189 3 2097.0773 Prob > F = 0.0000  
 Residual │ 2797.56589 68 41.1406748 R-squared = 0.6922  
─────────────┼────────────────────────────────── Adj R-squared = 0.6786  
 Total │ 9088.79778 71 128.011236 Root MSE = 6.4141  
  
─────────────┬────────────────────────────────────────────────────────────────  
 Height5 │ Coef. Std. Err. t P>|t| [95% Conf. Interval]  
─────────────┼────────────────────────────────────────────────────────────────  
 Fertilizer │ -14.71947 1.511991 -9.74 0.000 -17.73661 -11.70234  
 Height0 │ .8631456 .374817 2.30 0.024 .11521 1.611081  
 Competition │ 10.52346 1.52143 6.92 0.000 7.48749 13.55942  
 \_cons │ 39.22163 6.189971 6.34 0.000 26.86974 51.57353  
─────────────┴────────────────────────────────────────────────────────────────

The association of fertilizer with tree height is -14.72.

## Propensity Scores

The propensity score estimates the probability of being administered the treatment, in this example, *fertilizer*. Treatment observations are matched to the most similar comparison group observation in terms of this probability, and an average difference is calculated.

A propensity score analysis controls for the additional observed variables that are included in the model.

. teffects psmatch (Height5) (Fertilizer Height0 Competition)  
  
Treatment-effects estimation Number of obs = 72  
Estimator : propensity-score matching Matches: requested = 1  
Outcome model : matching min = 1  
Treatment model: logit max = 3  
─────────────┬────────────────────────────────────────────────────────────────  
 │ AI Robust  
 Height5 │ Coef. Std. Err. z P>|z| [95% Conf. Interval]  
─────────────┼────────────────────────────────────────────────────────────────  
ATE │  
 Fertilizer │  
 (NF vs F) │ -12.71019 1.988531 -6.39 0.000 -16.60763 -8.812737  
─────────────┴────────────────────────────────────────────────────────────────

The association of fertilizer with tree height is -12.71.

## Fixed Effects Regression

## Difference in Differences

## Multilevel Longitudinal Model

## “Hybrid” Model

# References 🌲

Camill, P., Chihara, L., Adams, B., Andreassi, C., Barry, A. N. N., Kalim, S., … Rafert, G. (2010). Early life history transitions and recruitment of Picea mariana in thawed boreal permafrost peatlands. *Ecology*. https://doi.org/10.1890/08-1839.1

Chihara, L. M., & Hesterberg, T. C. (2018). *Mathematical Statistics with Resampling and R*. https://doi.org/10.1002/9781119505969

Holland, P. W. (1986). Statistics and Causal Inference. *Journal of the American Statistical Association*, 81(396), 945–960. https://doi.org/10.1080/01621459.1986.10478354