Matt McCoy

EC 525

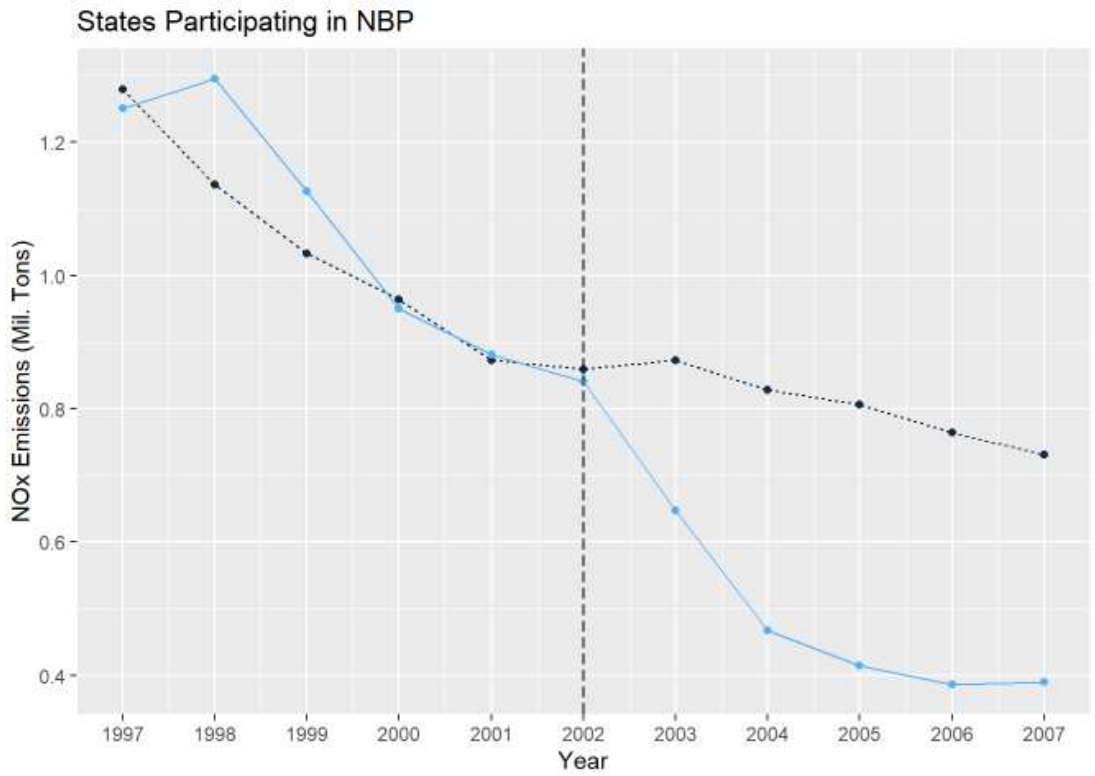
6/8/2021

Group partner: Jonathan Ely

Empirical Project 3

1. Some states had NBP while others did not have access to the program. The variable "summer"= 1 indicates that it is one of the summer months, and the variable will equal zero when it is not a summer month. "nbp" = 1 indicates that the state is regulated by the NBP. Lastly, the variable "post = 1" indicates that the year is post 2003.

2. Panel A:



3. The Parallel Trends Assumption states that the treatment and control trends in pre-treatment outcomes should be the same (parallel), even though treatment and control groups might have different levels of the outcome prior to the start of treatment. For us this means the difference in trends over time between regulated and unregulated states is similar for summer and winter seasons. Yes, judging by the graphical pattern it appears that this assumption will hold. Summer (solid line) is the treatment and winter (dashed line) is the control, and we can see that they are clearly moving in parallel with each other before the treatment in 2002. NBP operates only in the summer months and not the winter months. After 2002 the NOx emissions in the treatment group dropped significantly while the control group does not seem to be affected.
4. State DD: $\hat{\tau}^{DD} = [\overline{Y}\ (treated,\ post,\ summer)\ -\ \overline{Y}\ (treated,\ pre,\ summer)]\ -$

$[\overline{Y}\ (untreated,\ post,\ summer)\ -\ \overline{Y}(untreated,\ pre,\ summer)]$

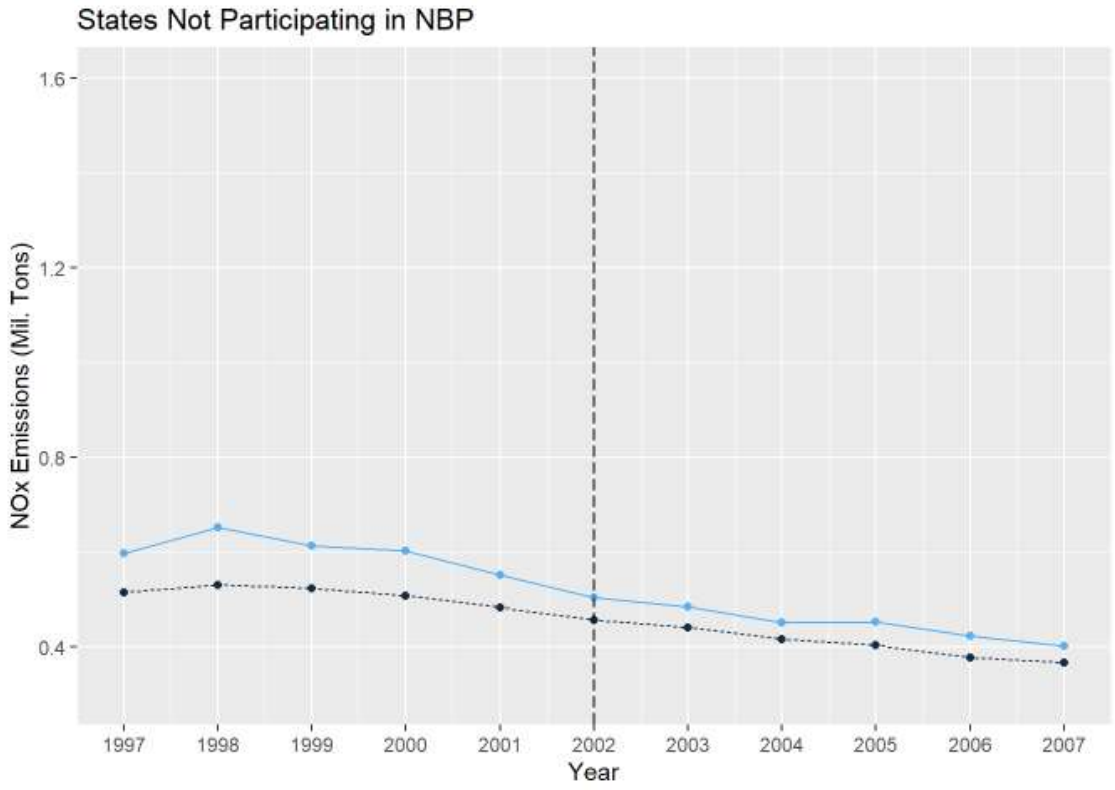
```
rega <- lm(nox_emit ~ summer*post, data = nbp_new)

stargazer(rega, type = 'text')
```

```
##
## ================================================
##                         Dependent variable:
##                     ---------------------------
##                                nox_emit
## ------------------------------------------------
## summer                          0.034
##                                (0.054)
##
## post                           -0.223***
##                                 (0.057)
##
## summer:post                    -0.373***
##                                 (0.080)
##
## Constant                       1.024***
##                                 (0.038)
##
## ------------------------------------------------
## Observations                    26,070
## R2                               0.005
## Adjusted R2                      0.005
## Residual Std. Error      3.233 (df = 26066)
## F Statistic          45.650*** (df = 3; 26066)
## ================================================
## Note:                *p<0.1; **p<0.05; ***p<0.01
```

The estimated coefficient "summer*post" tells us that the expected mean change in our outcome variable Y (NOx emissions) for states participating in the NBP program, before and after the NBP program was implemented, was different for the summer and winter months by -0.373.

5. Panel B:



6. The point of Panel B is to act as a placebo test to show that NBP does not reduce NOx emissions in states where the NBP is not in place. This also allows us to tell if a change in trends occurs due to treatment. If there is no treatment then you should not respond to the treatment, which is what we see here. This panel is also the DD estimate of the effect of NBP in non participating states needed for our DDD estimate.

7. State DD: $\hat{\tau}^{DD} = [\overline{Y}\ (treated,\ post,\ winter)\ -\ \overline{Y}\ (treated,\ pre,\ winter)]\ -$

$[\overline{Y}\ (untreated,\ post,\ winter)\ -\ \overline{Y}\ (untreated,\ pre,\ winter)]$

```
regb <- lm(nox_emit ~ summer*post, data = nbp_b)

stargazer(regb, type = 'text')
```

```
##
## ================================================
##                          Dependent variable:
##                      ---------------------------
##                                 nox_emit
## ------------------------------------------------
## summer                          0.084***
##                                  (0.033)
##
## post                            -0.102***
##                                  (0.034)
##
## summer:post                      -0.042
##                                  (0.048)
##
## Constant                        0.502***
##                                  (0.023)
##
## ------------------------------------------------
## Observations                     29,788
## R2                                0.001
## Adjusted R2                       0.001
## Residual Std. Error      2.074 (df = 29784)
## F Statistic          11.376*** (df = 3; 29784)
## ================================================
## Note:               *p<0.1; **p<0.05; ***p<0.01
```

The estimated coefficient “summer*post” tells us that the expected mean change in our outcome variable Y (NOx emissions) for states NOT participating in the NBP program, before and after the NBP program was implemented, was different for the summer and winter months by -0.042.

8. State DDD: $\hat{\tau}^{DDD} = DD\ in\ affected\ season\ -\ DD\ in\ unaffected\ season\ =$

$$\{[\overline{Y}\ (treated,\ post,\ summer)\ -\ \overline{Y}\ (treated,\ pre,\ summer)]\ -$$

$$[\overline{Y}\ (untreated,\ post,\ summer)\ -\ \overline{Y}(untreated,\ pre,\ summer)]\}$$

$$-$$

$$\{[Y\ (treated,\ post,\ winter)\ -\ Y\ (treated,\ pre,\ winter)]\ -$$

$$[Y\ (untreated,\ post,\ winter)\ -\ Y(untreated,\ pre,\ winter)]\}$$

```
reg_triple <- lm(nox_emit ~ summer*post*nbp, data = nbp_df)

stargazer(rega, regb, reg_triple, type = 'text')
```

```
##
## ================================================================================================
##                                          Dependent variable:
##                      ------------------------------------------------------------------------
##                                                nox_emit
##                              (1)                  (2)                   (3)
## ------------------------------------------------------------------------------------------------
## summer                       0.034               0.084***              0.084**
##                             (0.054)              (0.033)               (0.042)
##
## post                        -0.223***            -0.102***             -0.102**
##                             (0.057)              (0.034)               (0.044)
##
## nbp                                                                    0.522***
##                                                                        (0.043)
##
## summer:post                 -0.373***            -0.042                -0.042
##                             (0.080)              (0.048)               (0.062)
##
## summer:nbp                                                             -0.050
##                                                                        (0.062)
##
## post:nbp                                                               -0.121*
##                                                                        (0.065)
##
## summer:post:nbp                                                        -0.331***
##                                                                        (0.091)
##
## Constant                    1.024***             0.502***              0.502***
##                             (0.038)              (0.023)               (0.030)
##
## ------------------------------------------------------------------------------------------------
## Observations                26,070               29,788                55,858
## R2                           0.005                0.001                 0.009
## Adjusted R2                  0.005                0.001                 0.008
## Residual Std. Error    3.233 (df = 26066)   2.074 (df = 29784)    2.678 (df = 55850)
## F Statistic         45.650*** (df = 3; 26066) 11.376*** (df = 3; 29784) 68.541*** (df = 7; 55850)
## ================================================================================================
## Note:                                                          *p<0.1; **p<0.05; ***p<0.01
```

The coefficient for the interaction term “nbp*summer*post” relates to our answers to question 4 and question 7 because it is the difference between the estimates we got for those two

problems. In question 4 we got -0.373 and in question 7 we got -0.042. The estimate for "nbp*summer*post" is -0.331 which = (-0.373) - (-0.042) = -0.331. Rather than just comparing regulated vs. unregulated states pre vs. post, we can layer on summer and winter months as well in the DDD model. Question 4 is the $DD\ in\ affected\ season$ and questions 7 is the $DD\ in\ unaffected\ season$.

9. Panel A depicts an event study plot that measures the difference between NOx emissions in NBP and non NBP states and in summer compared to winter, separately by year. We normalized the year 2002 to take the value zero. The value for 2001 is nearly equal to zero, which is consistent with our parallel trends assumption. Panel B acted as a placebo test to show that NBP does not reduce NOx emissions in states where the NBP is not in place. Using the DDD estimator, we can calculate the effect on NOx emissions by multiplying the estimated impact of NBP on NOx emissions (-0.331) in million tons by the number of counties in the NBP (1,185). Multiplying this by the number of years NBP has been in place (5) and we will have the decrease in NOx emitted over the 5 year period. (0.331) * (1185)*(5) = 1961.174 million tons decrease in NOx emissions over the 5 year period NBP was in place (from 2003 to 2007).

Empirical Project 3

Matt McCoy

6/2/2021

```
## Install the pacman package if necessary
if (!require("pacman")) install.packages("pacman")
```

```
## Loading required package: pacman
```

```
## Install other packages using pacman::p_load()
pacman::p_load(tidyverse, haven, sandwich, lmtest, stargazer, dplyr, ggplot2, broom, magrittr)

getwd()
```

```
## [1] "C:/Users/mattm/OneDrive/Documents"
```

```
#Load in data
nbp_df <- read_dta(file = "nbp.dta")
```

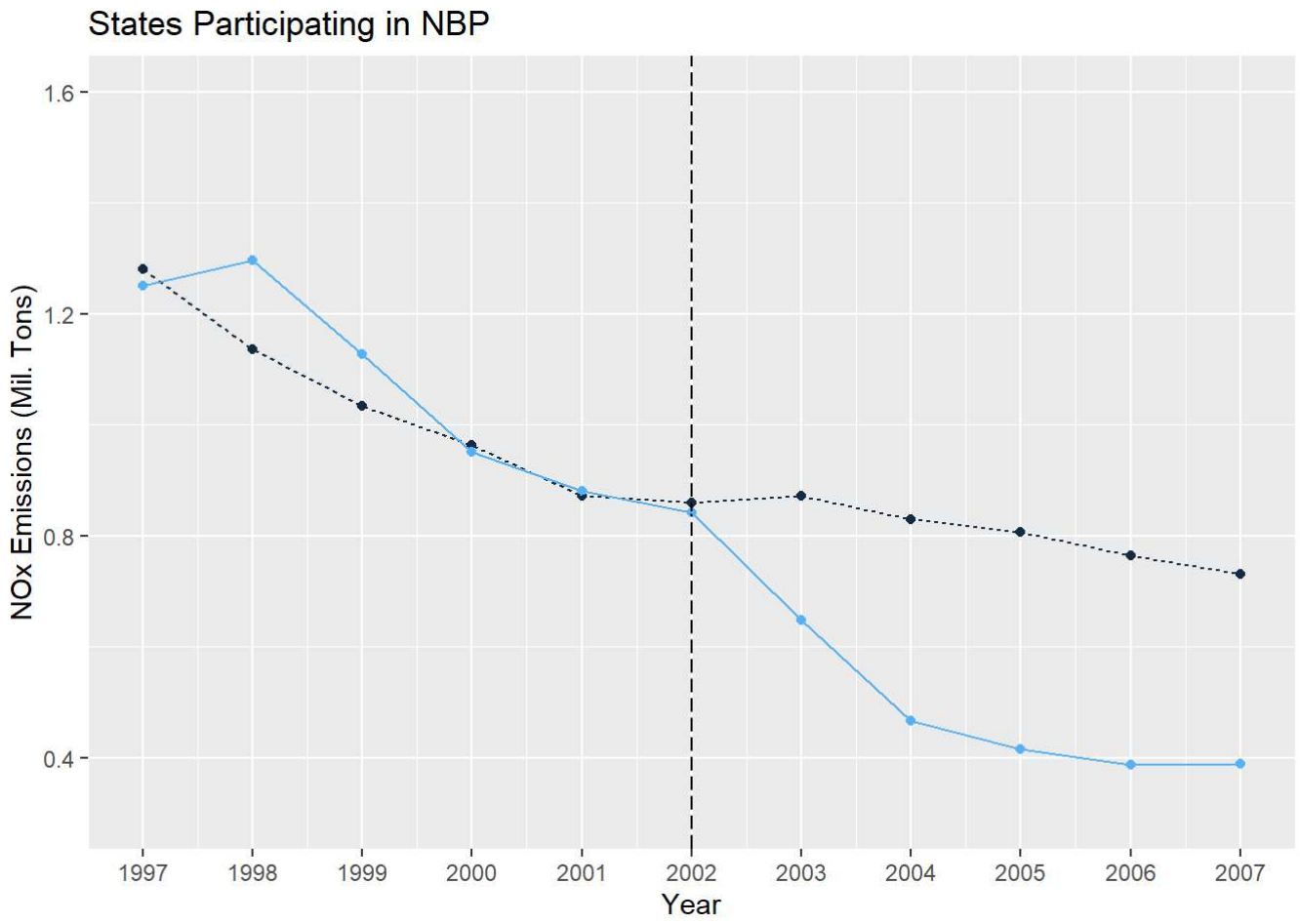
```
#subset data to only NBP participants
nbp_new <- subset(nbp_df, nbp ==1, select =
c(fips_county, fips_state, year, summer, post, nox_emit))

#nbp_new_new <- subset(nbp_new, summer ==1, select =
#c(fips_county, fips_state, year, post, nox_emit))

#nbp_solid <- nbp_new_new %>%
  #group_by(year) %>%
  #summarise(nox_emit = mean(nox_emit, na.rm = TRUE))
```

```
#re-create Panel A
nbp_new %>% group_by(year, summer) %>%
  summarise(nox_emit = mean(nox_emit, na.rm = TRUE)) %>%
  ggplot(aes(x = year, y = nox_emit, color = summer, group = summer)) + geom_point() + geom_vlin
e(xintercept=2002,linetype="longdash") +
  geom_line(aes(linetype = as.factor(-summer))) + ggtitle("States Participating in NBP") +
  labs(y="NOx Emissions (Mil. Tons)", x = "Year") + theme(legend.position = "none") + scale_x_co
ntinuous(breaks = 0:2100)  + ylim(.3, 1.6)
```

```
## `summarise()` has grouped output by 'year'. You can override using the `.groups` argument.
```




```
#First DD corresponding to Panel A
rega <- lm(nox_emit ~ summer*post, data = nbp_new)

stargazer(rega, type = 'text')
```

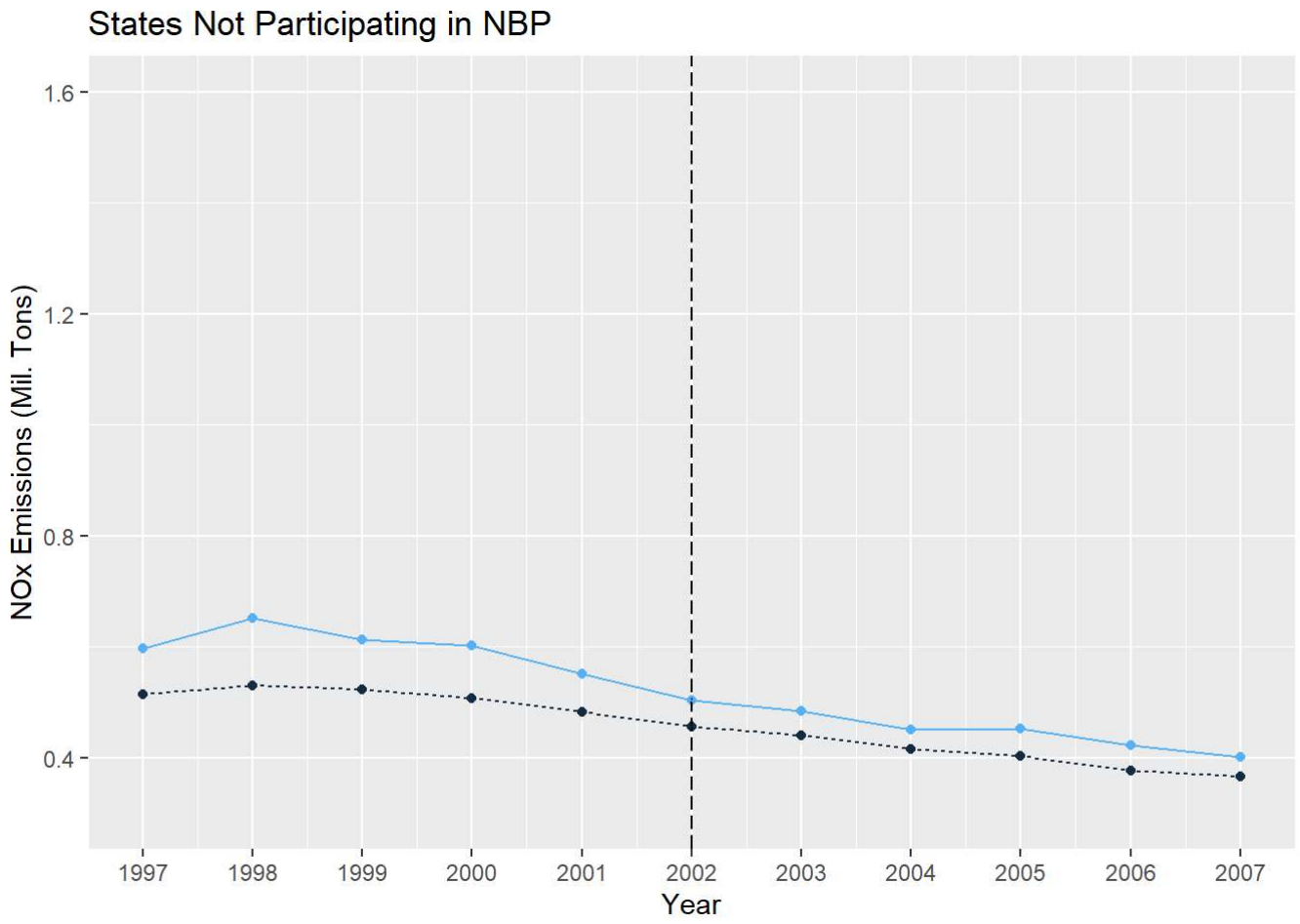
```
##
## ================================================
##                          Dependent variable:
##                      ---------------------------
##                                nox_emit
## ------------------------------------------------
## summer                          0.034
##                                (0.054)
##
## post                           -0.223***
##                                (0.057)
##
## summer:post                    -0.373***
##                                (0.080)
##
## Constant                       1.024***
##                                (0.038)
##
## ------------------------------------------------
## Observations                    26,070
## R2                               0.005
## Adjusted R2                      0.005
## Residual Std. Error      3.233 (df = 26066)
## F Statistic           45.650*** (df = 3; 26066)
## ================================================
## Note:                *p<0.1; **p<0.05; ***p<0.01
```

```
#subset data for Panel B, contains only non participating states

 nbp_b <- subset(nbp_df, nbp ==0, select =
c(fips_county, fips_state, year, summer, post, nox_emit))

#Re-create Panel B
nbp_b %>% group_by(year, summer) %>%
  summarise(nox_emit = mean(nox_emit, na.rm = TRUE)) %>%
  ggplot(aes(x = year, y = nox_emit, color = summer, group = summer)) + geom_point() + geom_vlin
e(xintercept=2002,linetype="longdash") +
  geom_line(aes(linetype = as.factor(-summer))) + ggtitle("States Not Participating in NBP") +
  labs(y="NOx Emissions (Mil. Tons)", x = "Year") + theme(legend.position = "none") + scale_x_co
ntinuous(breaks = 0:2100) + ylim(0.3, 1.6)
```

```
## `summarise()` has grouped output by 'year'. You can override using the `.groups` argument.
```




```
#DD corresponding to Panel B
regb <- lm(nox_emit ~ summer*post, data = nbp_b)

stargazer(regb, type = 'text')
```

```
##
## ================================================
##                          Dependent variable:
##                      ---------------------------
##                                nox_emit
## ------------------------------------------------
## summer                         0.084***
##                                 (0.033)
##
## post                           -0.102***
##                                 (0.034)
##
## summer:post                     -0.042
##                                 (0.048)
##
## Constant                       0.502***
##                                 (0.023)
##
## ------------------------------------------------
## Observations                    29,788
## R2                               0.001
## Adjusted R2                      0.001
## Residual Std. Error      2.074 (df = 29784)
## F Statistic           11.376*** (df = 3; 29784)
## ================================================
## Note:                *p<0.1; **p<0.05; ***p<0.01
```

```
# Extract just the diff-in-diff estimate
#diff_diff_controls <- tidy(did_reg2) %>%
  #filter(term == "summer:post") %>%
  #pull(estimate)
```

```
#Run DDD
reg_triple <- lm(nox_emit ~ summer*post*nbp, data = nbp_df)

stargazer(rega, regb, reg_triple, type = 'text')
```

```
##
## ================================================================================================
====
##                                                Dependent variable:
##                     ---------------------------------------------------------------------------
----
##                                                      nox_emit
##                                (1)                      (2)                      (3)
## ------------------------------------------------------------------------------------------------
----
## summer                          0.034                 0.084***                 0.084**
##                                (0.054)                  (0.033)                  (0.042)
##
## post                           -0.223***               -0.102***                -0.102**
##                                (0.057)                  (0.034)                  (0.044)
##
## nbp                                                                             0.522***
##                                                                                  (0.043)
##
## summer:post                    -0.373***                -0.042                   -0.042
##                                (0.080)                  (0.048)                  (0.062)
##
## summer:nbp                                                                       -0.050
##                                                                                  (0.062)
##
## post:nbp                                                                         -0.121*
##                                                                                  (0.065)
##
## summer:post:nbp                                                                 -0.331***
##                                                                                  (0.091)
##
## Constant                       1.024***                 0.502***                 0.502***
##                                (0.038)                  (0.023)                  (0.030)
##
## ------------------------------------------------------------------------------------------------
----
## Observations                    26,070                   29,788                   55,858
## R2                               0.005                    0.001                    0.009
## Adjusted R2                      0.005                    0.001                    0.008
## Residual Std. Error    3.233 (df = 26066)       2.074 (df = 29784)       2.678 (df = 55850)
## F Statistic         45.650*** (df = 3; 26066) 11.376*** (df = 3; 29784) 68.541*** (df = 7; 55
850)
## ================================================================================================
====
## Note:                                                                *p<0.1; **p<0.05; ***p<
0.01
```

```
#number of unique counties in the NBP
x <- unique(nbp_new$fips_county)
x <- as.data.frame(x)
nrow(x)
```

```
## [1] 1185
```