NBP Participation and NOx Emmission Reduction

Rhodes Kirkpatrick

6/7/2022

The variation introduced in the three variables (NBP participation, pre vs post implimentation, and summer vs winter seasonal participation) allow us to evaluate a triple difference in this quasi-experimental setting. NBP = 1 segregates the states that opted into the NOx (nitrogen oxides) trading program (NBP) from those that didn't. The NBP was a cap and trade marketplace where NOx quotas were openly available and necessary to pollute for all production. The solid line on the second figures (A & B) represents where the "post" variable would cut off this data, representing the implementation of the NBP (an exogenous intervention) for one of the two pools of data. With these two variables, we can create the first, difference in difference and regression discontinuity quasi-experiment. For the data that has the implementation, we can possibly make an identity assumption that the program caused a drop in emissions, and we can also look at the difference between both pools before and after emissions. Because the program only operated in the summer months however, we can further segment the data in both categories into summer and winter months (which is what the "summer" variable does). The reason why the study references "triple differences" is because we can look at the interaction between summer, post, and NBP. We can also look at exactly the months where the program took place and look across to states not in the program to see if there's no other summer manipulation going on. In summary; summer = 1 segregates the data of a given year into summer and winter, nbp = 1 segregates the states in the nbp programs from the ones that are not in the program, and post =1 segments the time of the data from before the program existed in 2003 from the time after 2003 and the program was in place.

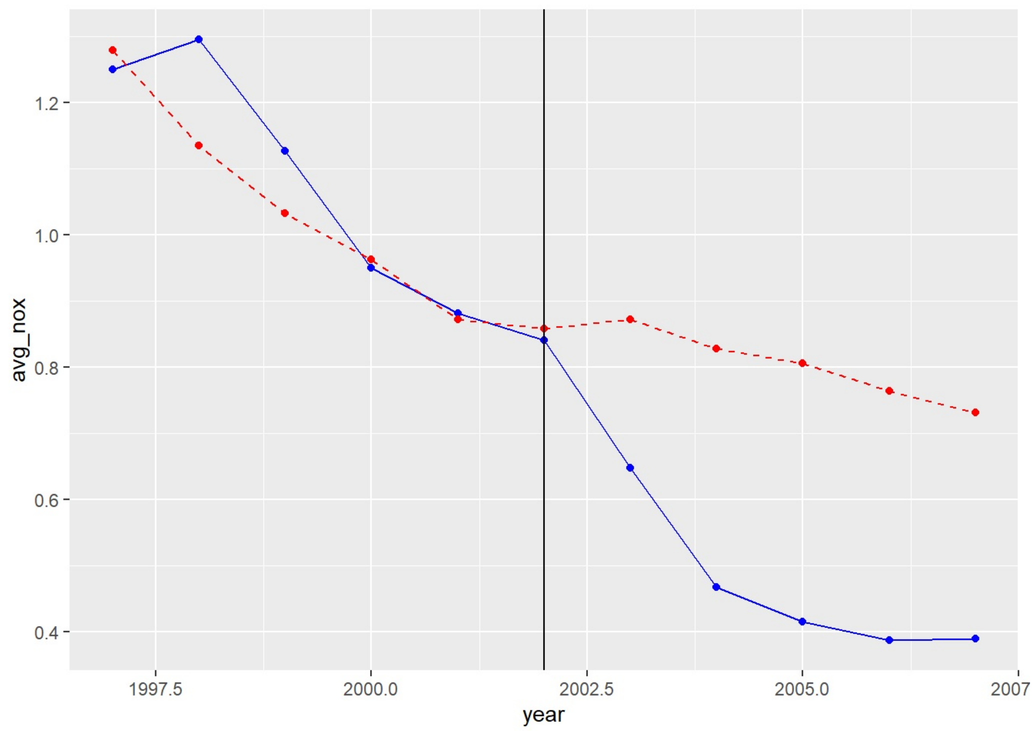
First Difference in Difference Chart:

```
## Rows: 55,858
## Columns: 7
## $ fips_county <dbl> 1001, 1001, 1001, 1001, 1001, 1001, 1001, 1001, 1001, 1001…
## $ year        <dbl> 1999, 2007, 2003, 1999, 2001, 2002, 2006, 2005, 2000, 2003…
## $ summer      <dbl> 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 1, 0, 0, 1, 1, 1, 1…
## $ nox_emit    <dbl> 0.000000000, 0.048699286, 0.011691429, 0.000000000, 0.0000…
## $ fips_state  <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1…
## $ nbp         <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1…
## $ post        <dbl> 0, 1, 1, 0, 0, 0, 1, 1, 0, 1, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1…
```

```
#new subset data frames for nbr=1 with average emissions by year

nbp2w = subset(nbp,nbp==1&summer==0)
nbp2w = nbp2w%>%group_by(year)%>%summarize(avg_nox=mean(nox_emit))
nbp2s = subset(nbp, nbp==1&summer==1)%>%
  group_by(year)%>%
  summarize(avg_nox=mean(nox_emit))
```

```
ggplot(data=NULL, aes(x=year,y=avg_nox))+geom_point(data=nbp2s,aes(x=year,y=avg_nox),color="blue")+geom_line(data
=nbp2s,aes(x=year,y=avg_nox), color="blue")+geom_point(data=nbp2w,aes(x=year,y=avg_nox),color="red")+geom_line(da
ta=nbp2w,aes(x=year,y=avg_nox), color="red",linetype = "dashed")+geom_vline(xintercept = 2002)
```



It is important to describe the parallel trends assumption which states that although both comparative groups may have different levels of some "Y" prior to treatment, the general trend should remain similar to each other. This is essentially the null hypothesis of a difference in difference model. It does not hold for states in the nbp, there is a difference in the difference between winter, the control, and Summer,the treatment. It holds for the states not in the NBP, further adding evidence that our identification assumption that the treatment during summer caused a breakage of the zero trend and parallel trend assumptions.

Results:

```
NBP_1=subset(nbp,nbp==1)
NBP_1 = NBP_1%>%group_by(year,summer,post)%>%summarize(avg_nox=mean(nox_emit))
```

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

```
DD1 = feols(avg_nox ~ summer + post + summer*post,data=NBP_1)
DD1 = as.data.frame((DD1[["coeftable"]]))
DD1
```

```
##                 Estimate Std. Error    t value     Pr(>|t|)
## (Intercept)  1.02398535 0.05931502 17.2635071 1.201215e-12
## summer       0.03379278 0.08388411  0.4028508 6.918025e-01
## post        -0.22341472 0.08797840 -2.5394270 2.054876e-02
## summer:post -0.37316871 0.12442025 -2.9992604 7.697783e-03
```

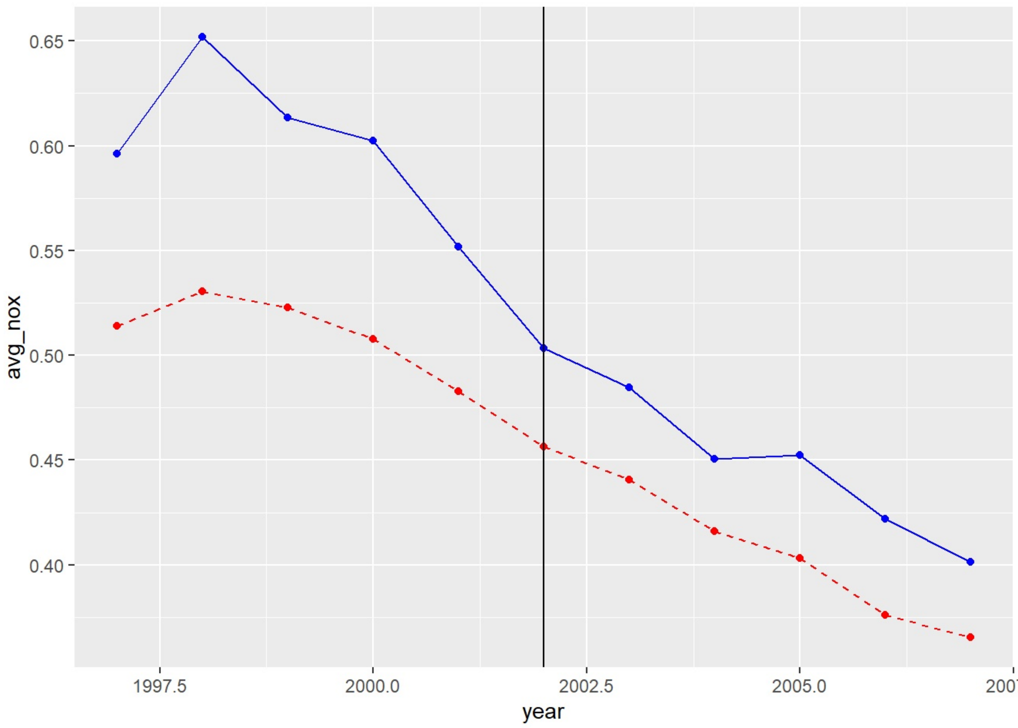
Summer:Post represents the difference in the difference as the treatment “summer” caused a .373 drop in average NOx emissions relative to the control group.

Second Difference in Difference Causal Inference:

```
#new subset data frames for nbr=0 with average emissions by year

nbp5w = subset(nbp,nbp==0&summer==0)
nbp5w = nbp5w%>%group_by(year)%>%summarize(avg_nox=mean(nox_emit))
nbp5s = subset(nbp, nbp==0&summer==1)%>%
  group_by(year)%>%
  summarize(avg_nox=mean(nox_emit))
```

```
ggplot(data=NULL, aes(x=year,y=avg_nox))+geom_point(data=nbp5s,aes(x=year,y=avg_nox),color="blue")+geom_line(data
=nbp5s,aes(x=year,y=avg_nox), color="blue")+geom_point(data=nbp5w,aes(x=year,y=avg_nox),color="red")+geom_line(da
ta=nbp5w,aes(x=year,y=avg_nox), color="red",linetype = "dashed")+geom_vline(xintercept = 2002)
```



Results: Panel B is a comparison, that there is no other factor associated/correlated with summer that is distorting the identification assumption that the NBP in summer is causing a lower emissions. It also allows for a triple difference. We can interact summer*post*nbr now instead of only summer*post or nbr*post.

Control Group Difference in Difference of Confounding Variable:

```
NBP_2=subset(nbp,nbp==0)
NBP_2 = NBP_2%>%group_by(year,summer,post)%>%summarize(avg_nox=mean(nox_emit))
```

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

```
DD2 = feols(avg_nox ~ summer + post + summer*post,data=NBP_2)
DD2 = as.data.frame((DD2[["coeftable"]]))
DD2
```

```
##                Estimate Std. Error   t value     Pr(>|t|)
## (Intercept)  0.50237864 0.01522175 33.004011 1.481375e-17
## summer       0.08412564 0.02152680  3.907950 1.030990e-03
## post        -0.10212768 0.02257750 -4.523428 2.630545e-04
## summer:post -0.04215831 0.03192940 -1.320360 2.032589e-01
```

The summer:post represents the .0421 decrease in summer emissions compared to winter months of the non-participating states after the program implementation. Even though they didn't participate in the treatment, this is a good comparison to check for confounding effects of summer.

Tripple Difference:

```
NBP_3 = nbp%>%group_by(nbp,year,summer,post)%>%summarize(avg_nox=mean(nox_emit))
```

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

```
DDD = feols(avg_nox ~ nbp + summer + post + summer*post + nbp*summer + nbp*post + nbp*summer*post,data=NBP_3)
DDD = as.data.frame((DDD[["coeftable"]]))
DDD
```

```
##                    Estimate Std. Error    t value     Pr(>|t|)
## (Intercept)      0.50237864 0.04330112 11.6019786 1.015740e-13
## nbp              0.52160670 0.06123703  8.5178317 3.755079e-10
## summer           0.08412564 0.06123703  1.3737708 1.780073e-01
## post            -0.10212768 0.06422594 -1.5901314 1.205499e-01
## summer:post     -0.04215831 0.09082919 -0.4641494 6.453354e-01
## nbp:summer      -0.05033286 0.08660224 -0.5811959 5.647298e-01
## nbp:post        -0.12128705 0.09082919 -1.3353311 1.901504e-01
## nbp:summer:post -0.33101040 0.12845187 -2.5769215 1.421337e-02
```

Nbp:summer:post represents the difference between the pre and post differences in summer and winter months of both groups. This suggests that there is causally a .33 drop in NOx emissions due to the summer implementation of the nbp program.

Conclusion: The program was a success as there was a significant drop of .331 particulates of Nitrogen Oxide levels from state enrollment and agency implementation, this amounts to a resounding 1.324 parts from 2003-2007. Using a Difference in the Difference (DD) in Difference (DDD) estimator, we were able to isolate the effect due to confounding of our summer variable being eliminated. We ran a DD model in the states that opted into the program (the one's where the effect would show) and took advantage of the natural counter factual of operations in winter being without the nbp market. Comparing these trends after the implementation leads us to a causal effect of summer nbp implementation, however, we can further take advantage of another counter factual to eliminate any other trends in winter vs summer emissions. We can control for these by taking the DD for before and after nbp program existence and then taking the difference between the two DDs isolates the effect of summer on the post period on the nbp enrolled states.