Estimating the Impact of Opioid Control Policies

Alex Bzdel, Charlotte Yuan, Zhonglin Wang, Annapurna Pandita

Motivation for Project

Opioid usage in the United States has increased substantially over the past two decades, leading to an increase in addiction to both prescription opioids and non-prescription illegal opioids. This has necessitated the enforcement of various opioid control policies. The White House's Office of National Drug Control Policy and the federal agencies such as the Drug Enforcement Agency (DEA) and the Department of Health and Social Services (DHSS) have made efforts to combat this national crisis. Across various parts of the US, state-level opioid control policies have also been implemented. For example, the states of Florida, Texas, and Washington implemented certain policy changes for pain treatment with opioids. The policy changes are as follows:

1. Florida (effective February, 2010)

   In 2007, Florida had witnessed a proliferation of pain clinics, which prescribed large quantities of drugs for pain with little medical justification and were being used majorly by people abusing or diverting opioids. Thus, in order to tackle these issues, the state legislature of Florida mandated the registration of pain clinics with controlled substances in 2010. The DEA and various Florida law agencies also joined hands to work together in Operation Pill Nation. The pain clinic regulations were continually expanded throughout 2010. In 2011, law enforcement conducted statewide raids, resulting in numerous arrests, seizures of assets, and pain clinic closures. In the same year, coinciding with a public health emergency declaration by the Florida Surgeon General, the state legislature prohibited physician dispensing of schedule II or III drugs from their offices and activated regional strike forces to address the emergency. Dispenser reporting to the newly established prescription drug monitoring program became mandatory. In 2012, the legislature expanded the regulation of wholesale drug distributors and created the Statewide Task Force on Prescription Drug Abuse and Newborns.
2. Texas (effective January 4, 2007)

   In 2007, the Texas Medical Board stipulated certain regulations for treating pain with controlled substances - performing a patient evaluation before prescribing opioids,

obtaining informed consent from the patient for opioid treatment, conducting periodic review of the opioid treatment and maintaining a complete medical record of the patient's treatment.

3. Washington (effective January 2, 2012)

   In 2011, the Washington Department of Health mandated certain prescription requirements for pain treatment by opioids. Annual periodic reviews became compulsory for patients who were stable involving non-escalating daily doses of 40 mg MED/day or less. Consultation threshold for adults had been set as 120 mg MED/day (oral). A consultation with a pain management specialist became a must, if a physician prescribed a dosage that met or exceeded consultation threshold. All mandatory consultations had to be documented by the physician. A practitioner could not prescribe more than an average MED of 120 mg without either the patient showing improvement in function or without first obtaining a consultation from a pain management expert.

However, it is also important to assess the effectiveness of these state-level policy interventions, which are designed to limit the over-prescription of opioids. This is because there is a troubling possibility that they cause unintended effects. For instance, even though they may reduce the likelihood that future patients will end up addicted to opioids, they may drive the already addicted patients to turn to alternative forms of opioids, such as illegally purchased prescription drugs, heroin, or fentanyl. Since the drug users (mostly) are unaware of the appropriate levels of dosage for a given strength of illegal drugs, there is a greater probability of overdosing on them than on prescription drugs. The potency of illegal drugs is great - a little as 3 milligrams of fentanyl can be lethal.

Thus, it is necessary to gauge and analyze the effects of state-level opioid control policies. This can help the policymakers to understand the strengths and weaknesses of the policies and accordingly improve or modify them for better welfare of people. This analysis aims to assess the causal effects of policy changes related to opioid drug prescription regulations on the volume of opioid shipments in Florida, Texas, and Washington and opioid overdose deaths in Florida, and Washington.

Motivation for Research Design

Our analysis will be grounded in causal inference while determining the answers to the following research questions.

1) What is the effect of the opioid control policies on the volume of opioid shipments and opioid overdose deaths during the period of 2003-2015 in Florida and Washington?
2) What is the effect of the opioid control policies on opioid overdose deaths in Texas during the period of 2003-2015?

Our analysis will primarily employ two approaches to estimate the causal effects of the policy changes in the three states. They are -

1) Pre-Post Analysis - The pre-post approach to analysis will involve the comparison of the outcomes - the volume of opioid shipments and the number of drug overdose deaths - before and after the implementation of the policy changes in the states.
2) Difference-In-Difference Analysis - A pre-post comparison is an intuitive approach to causal inference, but it is not without its problems. Suppose, for example, that around 2012 (the same time Washington's policy went into effect) the US Customs service managed to dramatically reduce the importation of fentanyl into the United States. This would likely reduce the amount of overdose deaths throughout the United States, and so if we were just comparing Washington in 2011 to Washington in 2013, we would see a decline in overdose deaths and wrongly attribute that to Washington's policy change. One strategy for dealing with this is what's called a difference-in-difference approach. In simple terms, we don't just compare Washington in 2011 to Washington in 2013; instead, we ask "were there bigger changes in overdose deaths in Washington between 2011 and 2013 than in other states that didn't change their opioid policy?" If Washington's policy had an effect, then we would expect opioid overdose deaths in Washington to decrease differently than opioid overdose deaths in states without a policy change. But if Washington experienced a decline in overdose deaths because of something that happened nationally (e.g. if US Customs blocked opioid importation), then we would

expect to see overdose deaths to reduce at the same rate in all states. In other words, if we see a decline in Washington overdoses, we want to know whether the change we saw in Washington (the "difference" from pre-to-post) is larger than the change that occurred in other states over the same period. Or, to map this onto the term "difference-in-difference," if we estimate the difference between 2011 and 2013 separately for Washington and states without policy changes, is there a difference in those differences?

Thus, the difference-in-difference approach will compare the changes in outcomes (the volume of opioid shipments and the number of drug overdose deaths) over time between a state with policy changes and other states where no policy changes have been implemented.

Both types of analysis will utilize single-variable regression-based approaches that observe if a trend line changes directly before and after the implementation of policy changes. By isolating the problem to the specific, controlled constraints, we are able to confidently derive whether a policy has changed a variable over time.

Data Preparation

Data Sources

The following sources were used for obtaining the relevant data.

1) Vital Statistics Mortality Data: This is the best national source of data on drug overdoses, since it includes data on every death in the United States. The statistics comprise the number of deaths each year, broken down by each county, and includes the cause of death as qualified by drug or alcohol induced. [1]
2) Opioid Drug Shipment Data: This dataset, released in 2020, by the Washington Post, contains the data on all prescription opioid drug shipments in the United States from 2006 to 2014. This data was obtained through a Freedom of Information Act (FOIA) request to the US Drug Enforcement Agency (DEA). [2]
3) US Census Population Data: This dataset has the information regarding population in all counties across the United States, which is required for the normalization of the outcome variables in the analysis (eg: opioid overdose deaths per 100,000 residents). [3]

Data Cleaning

Through a series of cleaning steps, this data was aggregated annually for opioid drug overdose deaths and monthly for opioid shipments (due to the granularity of the data when retrieved). Additionally, we wanted to normalize overdose deaths over county population (and therefore analyzed overdose deaths per 100,000 residents). This was done by creating a unique FIPS ID based on a concatenation of county and state FIPS IDs. We joined these unique FIPS numbers to the datasets on opioid shipments and overdose deaths separately. Joining these FIPS numbers accurately was a challenge at first due to inconsistencies in how each dataset labeled counties and states, but after cleaning these fields accordingly, this was done. We encountered issues, while adding in FIPS numbers, because some counties were present in the FIPS (population) dataset (eg. populations of every state and county across the years), but not present in either the datasets on overdose deaths or opioid shipment. The first issue we noticed was simple name inconsistencies in counties. For example, “Franklin” in one dataset may be labeled “FRANKLIN COUNTY” in the other dataset with which we want to join. Thus, our first step was to convert every county name to lowercase. After that, the name inconsistencies for counties had to be solved.. To do this, we removed the words “county” and “parish” from every record in the county column. The only time this caused ambiguity was with one county name appearing in two states: “La Salle County " and “La Salle Parish " in another. However, since we had joined the FIPS numbers based on counties and states, we concluded that this issue can safely be ignored. Some county names that appeared differently in the different datasets were expanded or abbreviated accordingly (saint to st, desoto to de soto, etc.).

After performing these steps, we found that some counties were still not merging from the FIPS dataset to the datasets on opioid shipment and overdose deaths. In both cases, they were missing from the latter datasets (FIPS dataset has data from every county in the US). For the opioid shipment dataset, we concluded that it was a fair assumption that the counties not present in the opioid shipment dataset simply did not have any shipments, so we imputed these values with zeros. In order to account for different units and dosages of opioid drugs present in the transactions, a new variable had to be calculated. By multiplying the total active weight of the an opioid drug in grams with MME Conversion Factor (Morphine Milligram Equivalent, or how the

specific drug compares to a morphine equivalent), the new variable called MME was obtained, which basically estimates the total amount of morphine shipped to different localities and is a unit of measurement used in this analysis. For the dataset on overdose deaths, we had to employ a more complicated process. The Washington Post informs us that their data does *not* have records for counties where deaths are less than ten in a given year. Removing these outright would result, therefore, in data biased towards counties with more deaths. The solution employed was to fill in each record with a random integer from zero through nine.

Another question that arose during data cleaning was which causes of death should be considered for the analysis. We decided that *all* columns referring to "drug poisoning" should be included, and nothing more. One contentious value we found is labeled as "all other drug-induced cases", but we determined that this was too ambiguous to accredit to opioid overdoses specifically. One more caveat that was discovered is that the dataset for national opioid shipments from the Washington Post did not contain two years of interest - 2013 and 2014. "The DEA produced data from 2006 through 2014…We know that 2013 and 2014 data exists, but we have not been able to get access because of the ongoing court case in Ohio" [2] . Interestingly, the data for each individual state did contain records for these years. Therefore, individual state opioid shipment data (MME per 100,000 residents) was aggregated and used for each target state and their comparison states.

Control States

For our analysis, we chose three control states (for each target state) based on similarity in terms of opioid overdose deaths over the years.

For Florida, the chosen control states are Pennsylvania (PA), Michigan (MI), and North Carolina (NC). Figure 1 compares opioid overdose deaths in Florida and its control states. For Texas, the chosen control states are Massachusetts (MA), Michigan (MI), and Illinois (IL). Figure 2 compares opioid overdose deaths in Texas and its control states. The control states chosen for Washington are Maryland (MD), North Carolina (NC), and Colorado (CO). Figure 3 compares opioid overdose deaths in Washington and its control states. We determined that these control

states had similar trends in opioid overdose deaths when compared to their target states and thus, they could be used for a causal inference analysis.

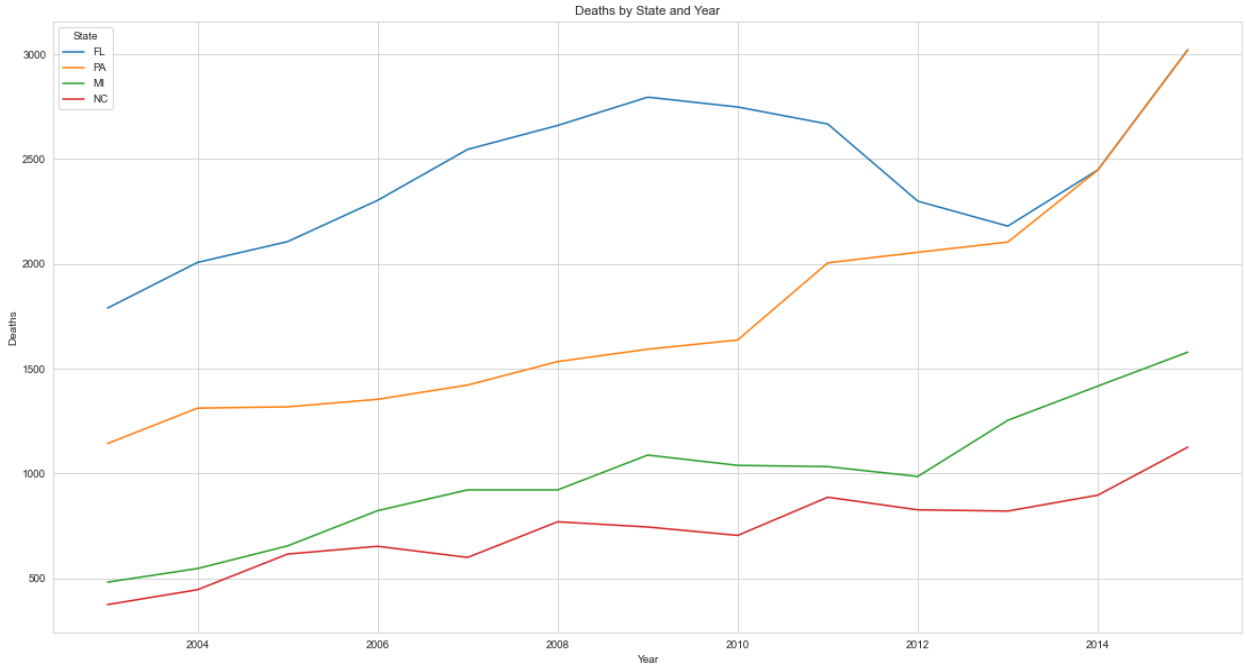

Figure 1: Opioid overdose deaths in Florida, Pennsylvania, Michigan, and North Carolina

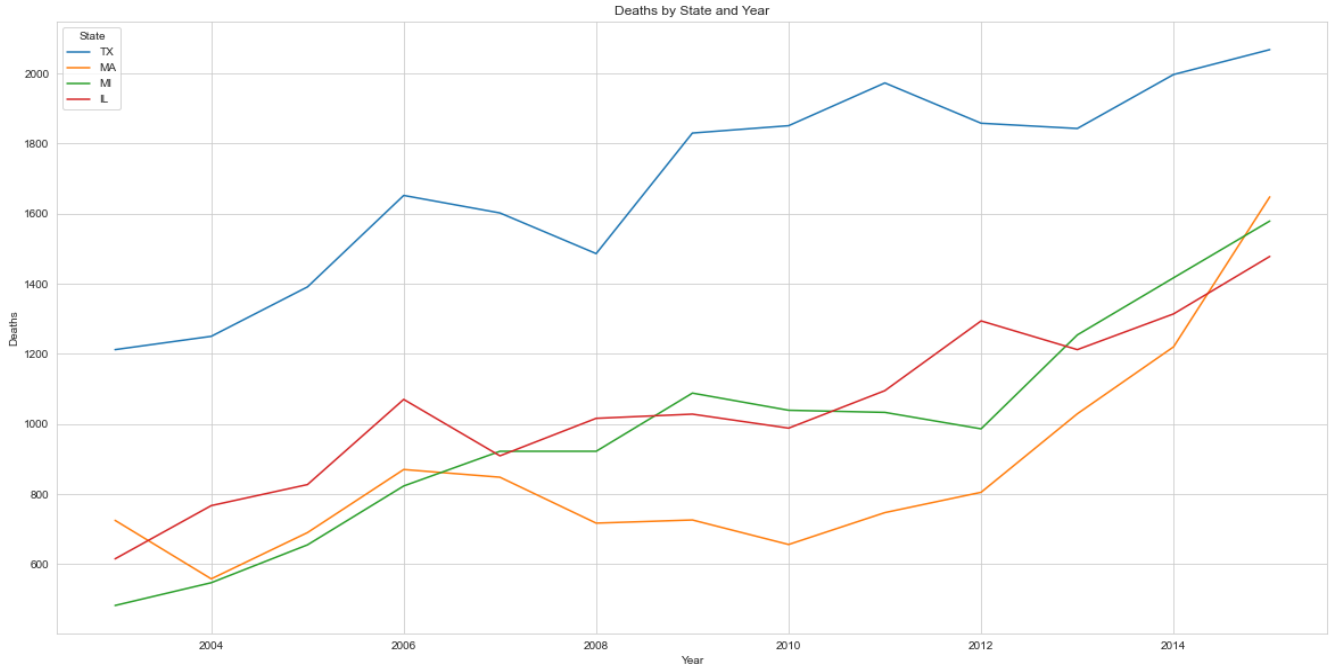

Figure 2: Opioid overdose deaths in Texas, Massachusetts, Michigan, and Illinois

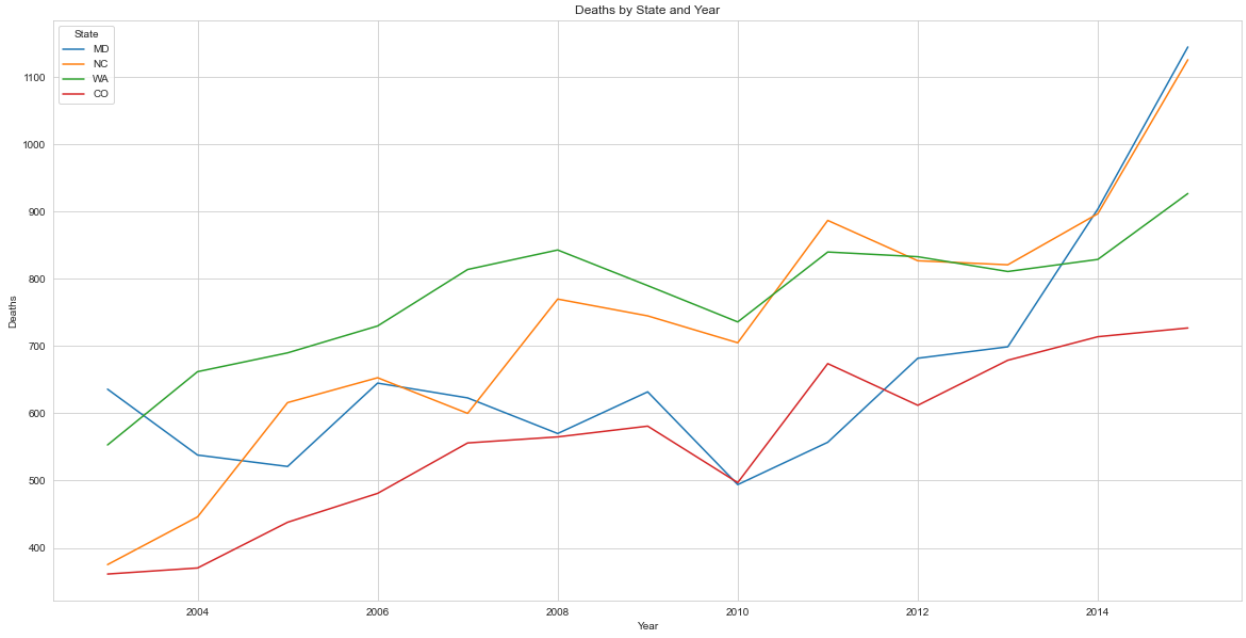

Figure 3: Opioid overdose deaths in Washington, Maryland, Colorado, and North Carolina

Methodology

The three datasets helped in assessing the effects of opioid control policies on opioid overdose deaths (Florida, Texas, Washington) and opioid shipments (Florida, Washington) and also comparing their rates to those in the control states where the policies had not been implemented. The subset of data for analysis was created by filtering for death causes which were drug overdose related. The number of deaths was then divided by population and multiplied by 100,000 for a normalized calculation of opioid overdose death rates. We further grouped the dataset by year and averaged the overdose deaths in all counties in a given year to compute the observations for plotting. Data were split into treatment and control states, and categorized yearwise - before and after implementation of opioid control policies. Similarly, the volume of opioid shipments was standardized by dividing MME by population and multiplying 100,000 to calculate opioid shipments (MME per 100,000 residents). Data were grouped by year to calculate the mean of opioid shipments in a given year among all counties to prepare observations for plotting. Likewise, data were split into treatment and control states, then further categorized yearwise - before and after implementation of opioid control policies. Univariate linear regression was performed on the outcomes - opioid overdose deaths and opioid shipments against each year. For pre-post analysis, two regression lines and confidence intervals of the treatment state are plotted before and after policy implementation. For difference-in-difference analysis, four regression lines along with confidence intervals of the treatment state and three control states are plotted before and after policy implementation.

Summary Statistics

Opioid Overdose Deaths

Texas - The mean, median and minimum values of opioid overdose deaths per 100000 residents increase in Texas after the implementation of the policy changes in 2007. The maximum value however drops. A more substantial increase can be seen in all four values of opioid overdose deaths per 100000 residents for the control states after 2007. Table 1 shows the summary statistics of opioid overdose deaths in Texas and its control states - Massachusetts, Illinois and Michigan.

State	W.R.T. Policy	Mean	Median	Minimum	Maximum
Control States (MA, IL, MI)	Before	9.41	8.95	8.32	10.95
	After	11.88	11.94	11.29	12.36
Texas	Before	10.05	9.22	8.10	12.83
	After	10.55	10.48	9.68	11.56

Table 1. Summary statistics of opioid overdose deaths per 100,000 residents in Texas and its control states

Washington - The mean, minimum and maximum values of opioid overdose deaths per 100000 residents increase in Washington after the implementation of the policy changes in 2012. The median value however drops. A more substantial increase can be seen in all four values of opioid overdose deaths per 100000 residents for the control states after 2012. Table 2 shows the summary statistics of opioid overdose deaths in Texas and its control states - Maryland, North Carolina, and Colorado.

State	W.R.T. Policy	Mean	Median	Minimum	Maximum
Control States (MD,NC,CO)	Before	14.17	14.17	12.51	15.82
	After	15.55	14.81	13.80	18.77
Washington	Before	13.49	14.17	12.02	14.28
	After	13.80	13.77	13.31	14.35

Table 2. Summary statistics of opioid overdose deaths per 100,000 residents in Washington and its control states

Florida - The mean, median, and minimum values of opioid overdose deaths per 100000 residents decrease in Florida after the implementation of the policy changes in 2010. The maximum value however increases. A substantial increase can be seen in the mean, median and maximum values of opioid overdose deaths per 100000 residents for the control states after 2010. The minimum value however witnesses a slight drop. Table 3 shows the summary statistics of opioid overdose deaths in Florida and its control states - Pennsylvania, Michigan, and North Carolina.

State	W.R.T. Policy	Mean	Median	Minimum	Maximum
Control States (PA, MI, NC)	Before	13.72	12.10	3.81	43.32
	After	15.40	14.40	3.78	62.55
Florida	Before	15.86	15.55	4.84	35.88
	After	14.95	14.13	3.90	37.16

Table 3. Summary statistics of opioid overdose deaths per 100,000 residents in Florida and its control states

Opioid Shipment

Washington - The mean, median, and minimum values of opioid shipment (MME per 100000 residents) increase in Washington after the implementation of the policy changes in 2012. The maximum value however decreases. A substantial increase can be seen in all four values for the control states after 2012. Table 4 shows the summary statistics of opioid shipment in Washington and its control states - Maryland, Colorado, and North Carolina

State	W.R.T.Policy	Mean	Median	Minimum	Maximum
Control States (MD,NC,CO)	Before	39837.53	40158.80	36133.56	43220.23
	After	44158.75	44259.06	43536.10	44681.09
Washington	Before	76808.29	77468.98	75058.20	77897.69
	After	77487.65	77489.84	77317.16	77655.94

Table 4. Summary statistics of opioid shipment (MME) per 100,000 residents in Washington and its control states

Florida - All four values of opioid shipment (MME per 100000 residents) increase in Florida after the implementation of the policy changes in 2010. A substantial increase can be seen in all four values for the control states also after 2010. Table 5 shows the summary statistics of opioid shipment in Florida and its control states - Pennsylvania, Michigan, and North Carolina.

State	W.R.T. Policy	Mean	Median	Minimum	Maximum
Control States (PA,MI,NC)	Before	33429.18	33026.10	30583.29	36678.18
	After	42360.75	42772.40	39345.81	44552.41
Florida	Before	47322.98	46442.37	38192.19	57334.38
	After	56526.93	56633.96	39785.73	73054.09

Table 5: Summary statistics of opioid shipment (MME) per 100,000 residents in Florida and its control states

Analysis - Estimating effects of opioid control policies on opioid shipment

Florida

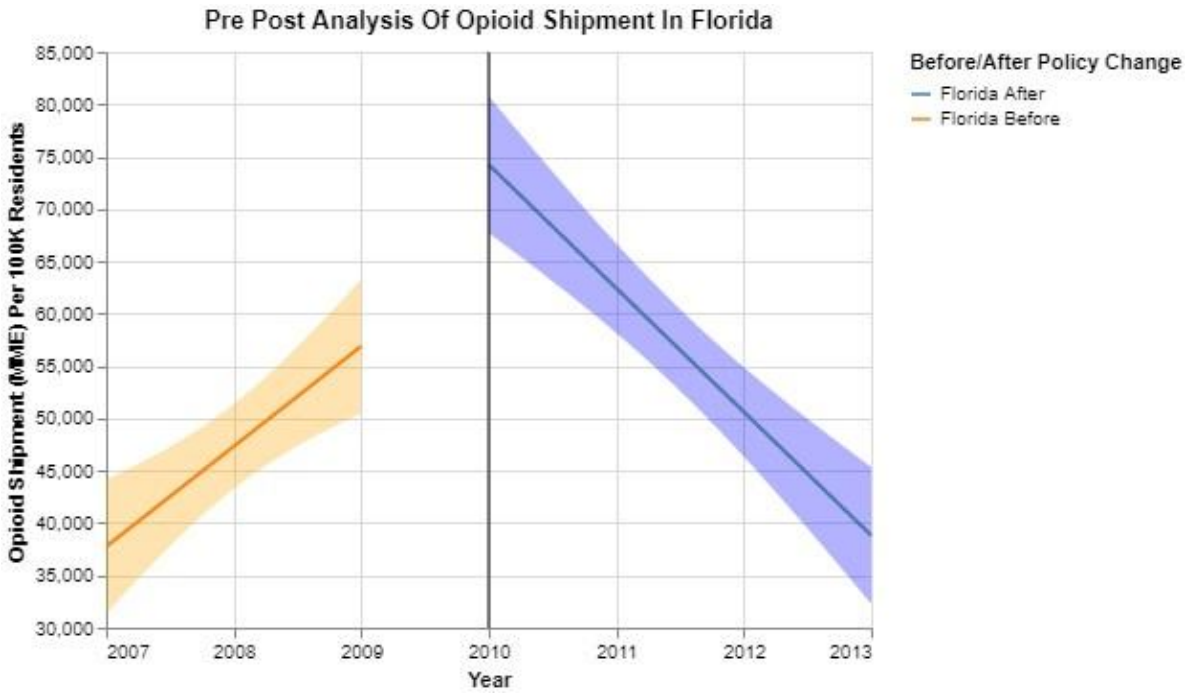

Figure 4: Opioid shipment in Florida - before and after policy changes in 2010

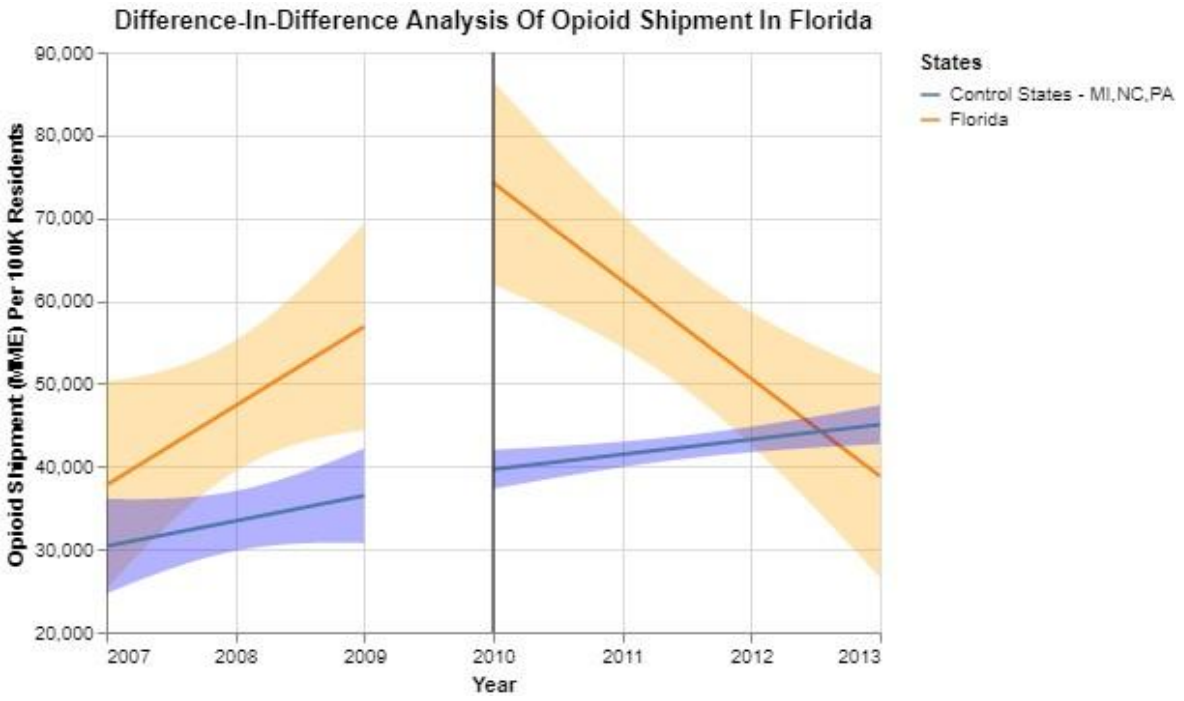

Figure 5: Opioid shipment in Florida and its control states- before and after policy changes in 2010

In Figure 4, it can be seen that before the implementation of opioid control policies there was a rapid increase in the opioid shipments in Florida. But after the implementation of the policy changes in 2010, a rapid and substantial decrease can be seen in the opioid shipment (MME per 100,000 residents). From the pre-post analysis, it can be concluded that the policy changes have reduced opioid shipment in Florida. But to be doubly sure about this conclusion and with the drawbacks of pre-post analysis, a difference-in-difference analysis needs to be conducted too. Thus, the rate of opioid shipment in Florida is compared to the rate of opioid shipment in the control states - Pennsylvania, Michigan, and North Carolina. Figure 5 shows that before 2010, there was a somewhat similar trend for Florida and the control states - there was an increase in the opioid shipment. In fact, the rate of increase was higher for Florida than for the control states. But after the implementation of policy changes in 2010, it can be seen that the opioid shipment continued to increase steadily for the control states, meanwhile Florida witnessed a drastic drop in opioid shipments. Thus, we can more confidently affirm that the opioid control policies have reduced opioid shipments in Florida.

Washington

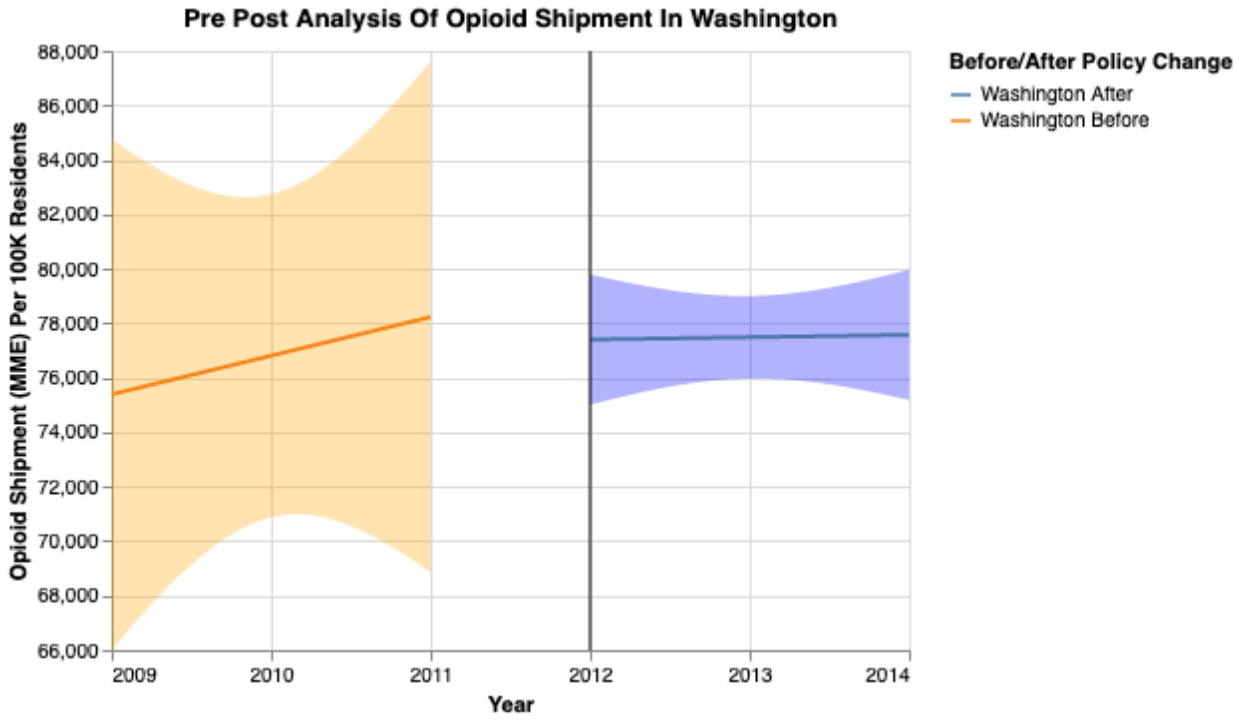

Figure 6: Opioid shipment in Washington - before and after policy changes in 2012

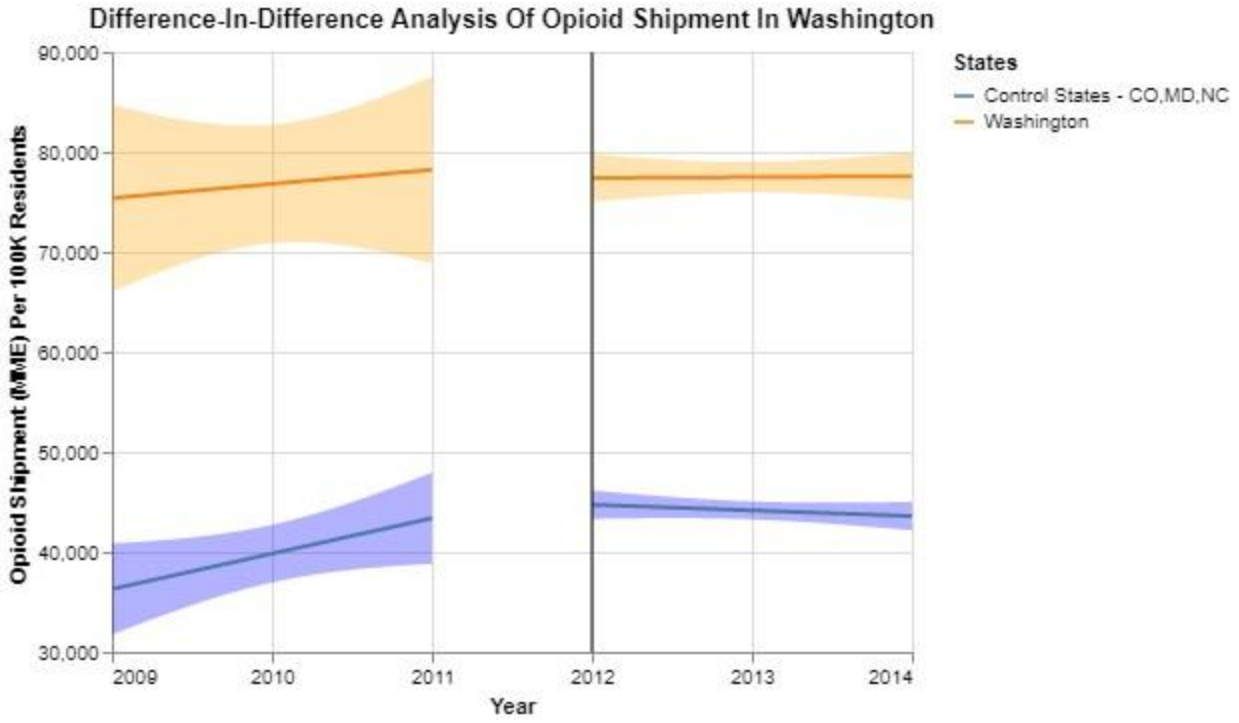

Figure 7: Opioid shipment in Washington and its control states- before and after policy changes in 2012

In Figure 6, it can be seen that before the implementation of opioid control policies there was a steady increase in the opioid shipment rates in Washington. But after the implementation of the policy changes in 2012, the rate of increase somehow gets flatlined. It can be understood that the policy changes implemented may have reduced the rate of opioid shipment. But with the drawbacks of pre-post analysis, we cannot reach this conclusion. The rate of increase of opioid shipment in Washington is compared with that of its control states - Colorado, Maryland, and North Carolina. It can be seen in Figure 7, that after 2012, even though no opioid control policies were implemented in those states, they witnessed a slight drop in the opioid shipments. The rate of decrease in the opioid shipment for these states is marginally greater than that of Washington. Perhaps, it can be concluded that the opioid control policies have minutely impacted the opioid shipment in Washington and slightly reduced them.

Analysis - Estimating effects of opioid control policies on opioid overdose deaths

Florida

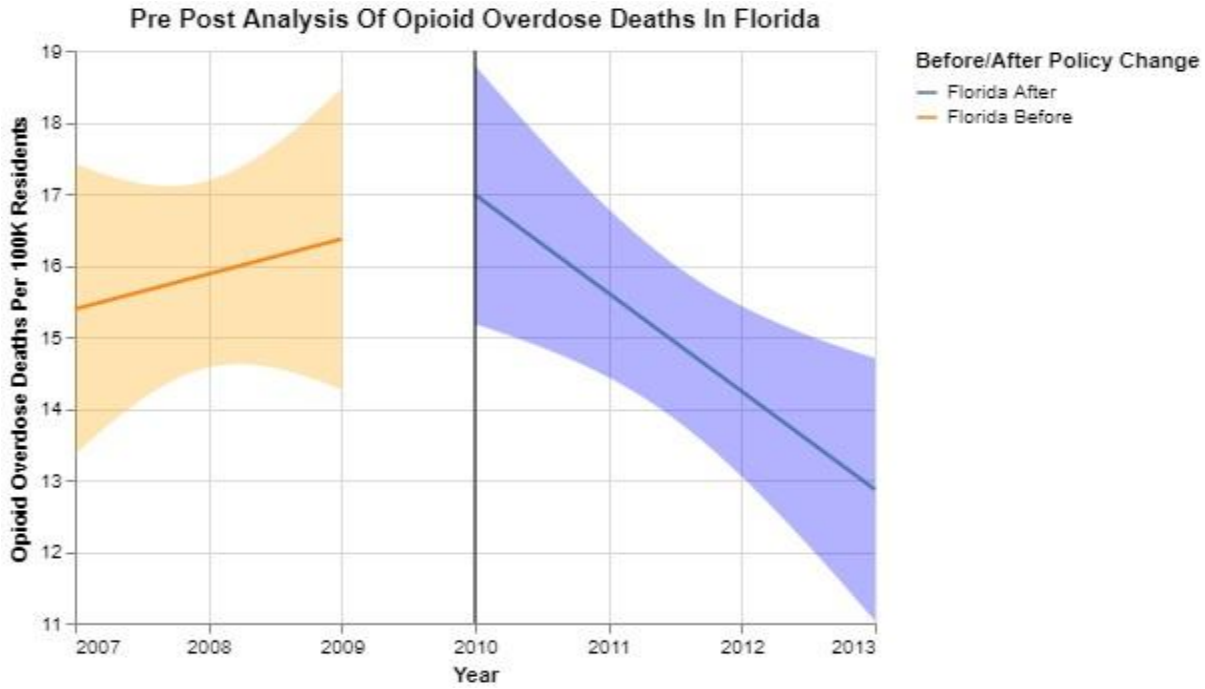

Figure 8: Opioid overdose deaths in Florida - before and after policy changes in 2010

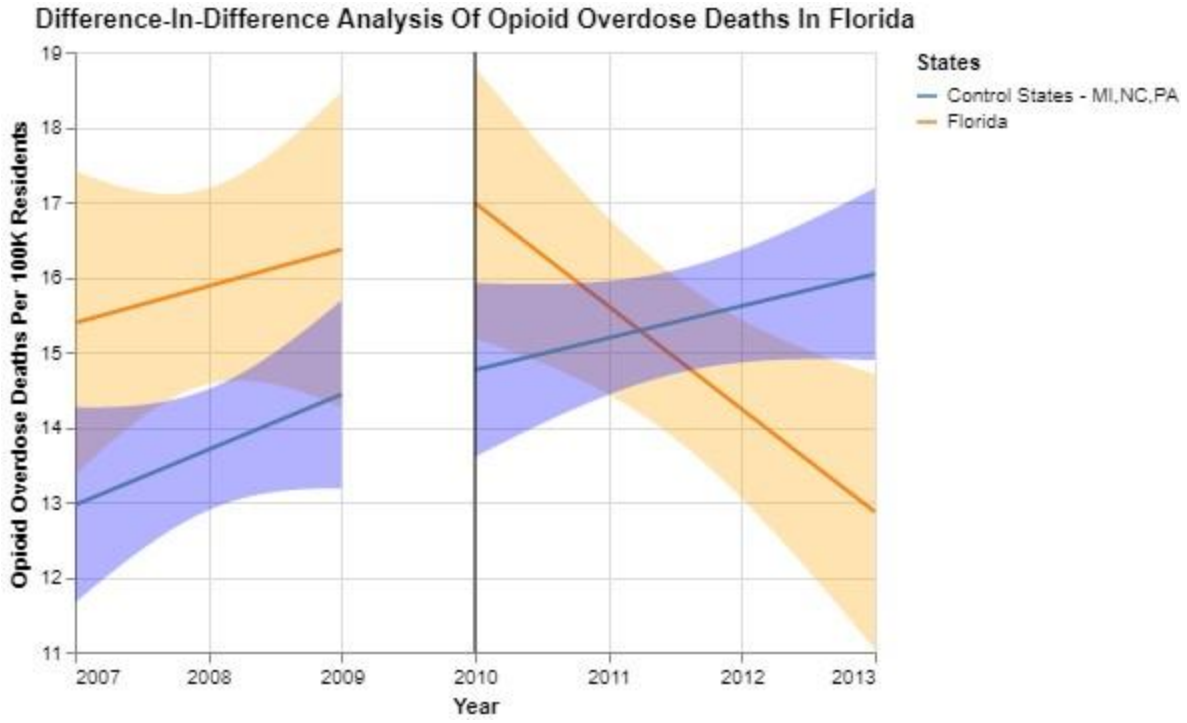

Figure 9: Opioid overdose deaths in Florida and its control states- before and after policy changes in 2010

In Figure 8, it can be seen that before the implementation of opioid control policies there was steady increase in the opioid overdose deaths. But after the implementation of the policy in 2010, a substantial decrease can be seen in the opioid overdose deaths. From the pre-post analysis, it can be concluded that the policy changes have reduced opioid overdose deaths in Florida. But to be doubly sure about this conclusion and with the drawbacks of pre-post analysis, a difference-in-difference analysis needs to be conducted too. Thus, the rate of opioid overdose deaths in Florida is compared to the rate of opioid overdose deaths in the control states - Pennsylvania, Michigan, and North Carolina. Figure 9 shows that before 2010, there was a similar trend in the rate of increase in opioid overdose deaths in Florida and its control states. But after 2010, the trends changed. After the implementation of policy changes in Florida, a drastic drop in rate of opioid overdose deaths is seen. On the contrary, in the control states, where no policy changes were implemented, the rise in rate of overdose deaths continues. Thus, we can more confidently affirm that the opioid control policies have reduced opioid overdose deaths in Florida.

Texas

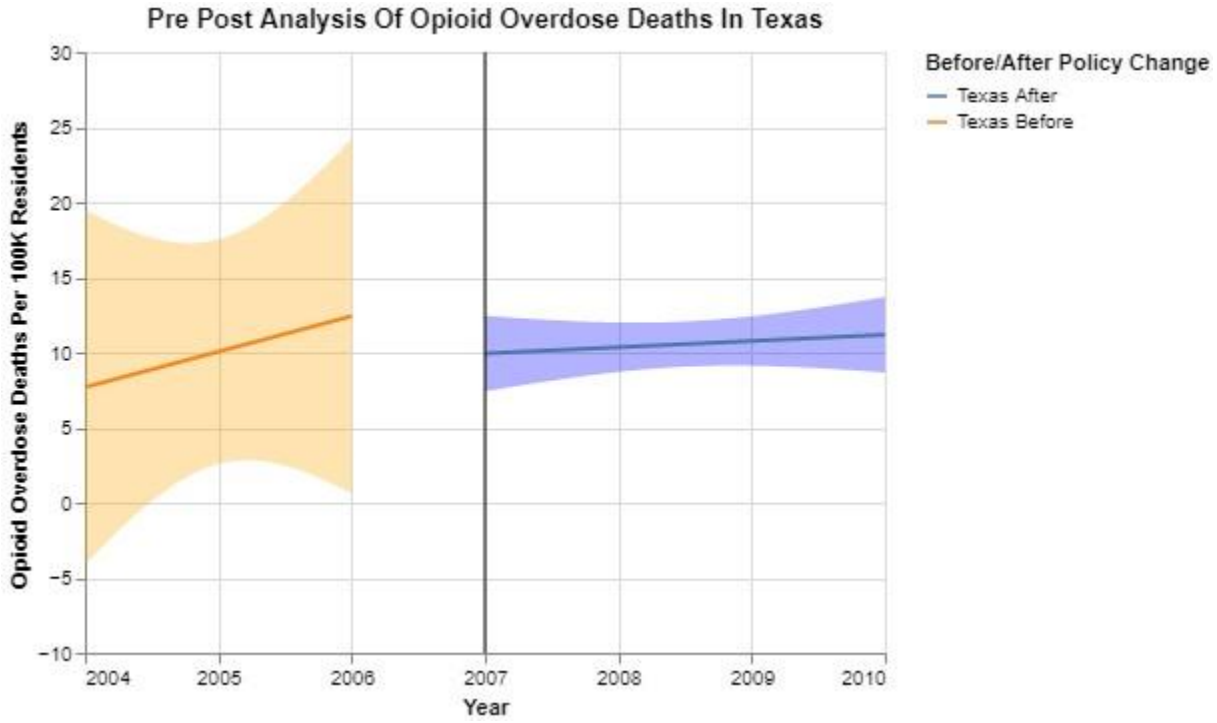

Figure 10:Opioid overdose deaths in Texas - before and after policy changes in 2007

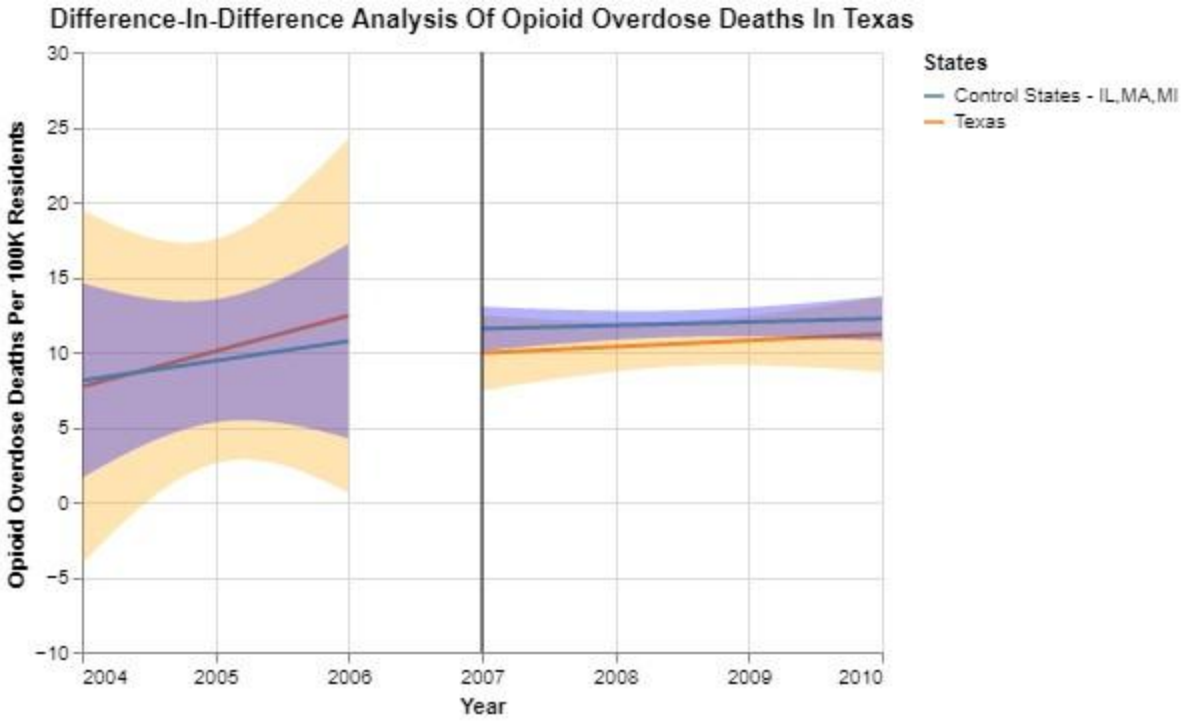

Figure 11: Opioid overdose deaths in Texas and its control states- before and after policy changes in 2007

From the figures 10 and 11, it can be seen that both Texas and its control states - Massachusetts, Illinois, and Michigan have a similar, steady upwards trend of opioid overdose deaths from 2004 to 2006. After the implementation of the policy changes in 2007, we see Texas' trend has more or less flatlined. However, the slope is still slightly positive and the average value seems to hover around the same as that of the pre-policy line (albeit with a much smaller confidence band). The difference-in-difference result helps add more context to the situation. It can be seen that the trend for the control states flattens out slightly, but for the most part stays on its upwards trajectory. It can thus be concluded that the policy changes have not significantly impacted the opioid overdose deaths in Texas

Washington

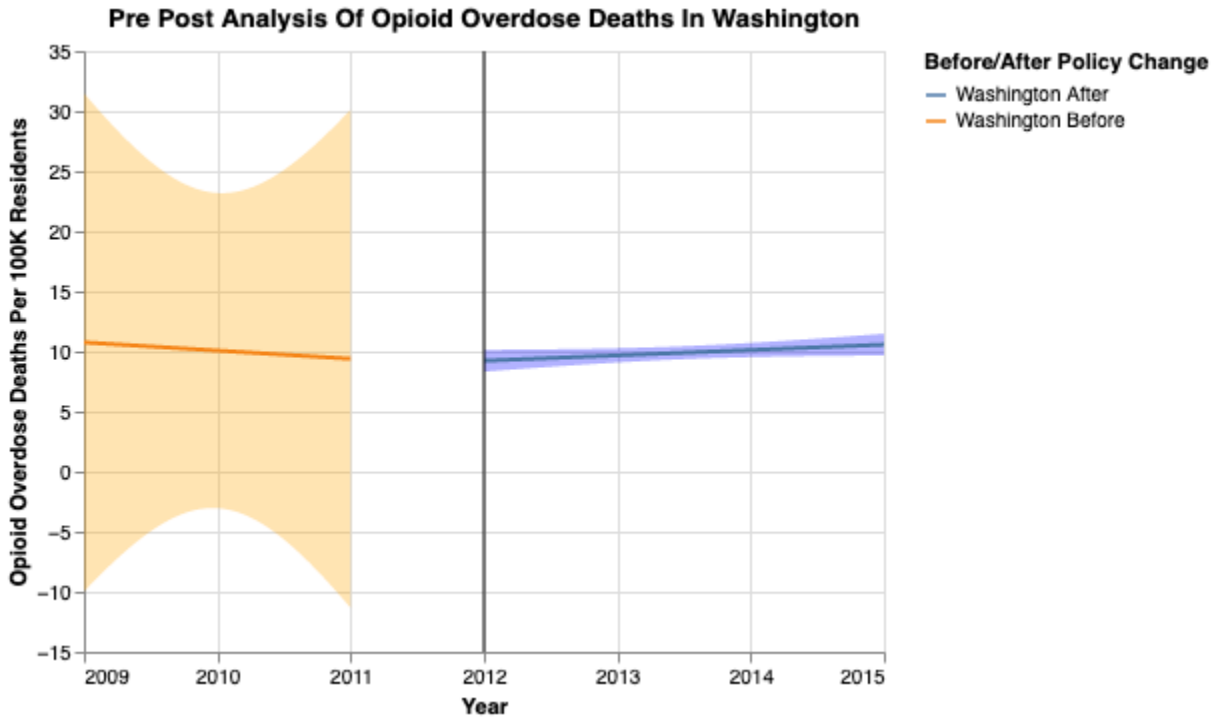

Figure 12: Opioid overdose deaths in Washington - before and after policy changes in 2012

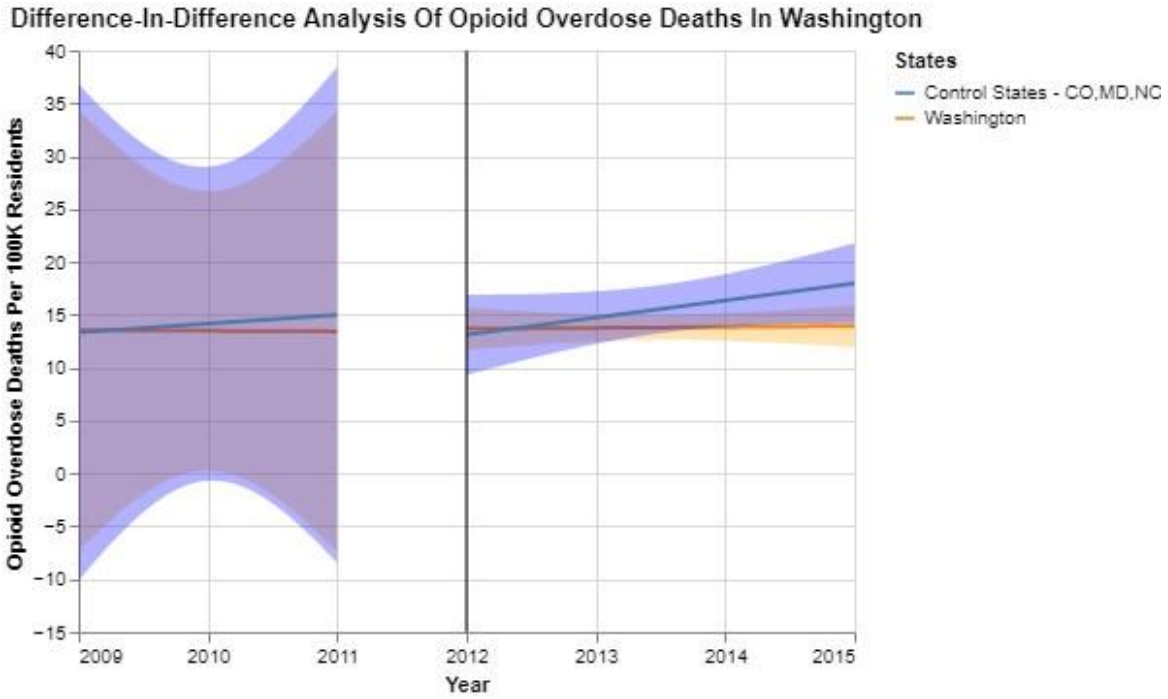

Figure 13: Opioid overdose deaths in Washington and its control states - before and after policy changes in 2012

In Figure 12, it can be seen that before the implementation of opioid control policies there was a minute, but visible decrease in the opioid overdose deaths. After the implementation of the policy changes in 2012, a minute, but visible increase can be seen in the opioid overdose deaths. It can be concluded with some certainty that the opioid control policies have not impacted the opioid overdose deaths in Washington and perhaps, on the contrary, there has been a reversal in the trend of decrease in opioid overdose deaths in Washington. The opioid overdose deaths have increased slightly after the implementation of the policy changes. However, in Figure 13, the result for difference-in-difference analysis shows that the rate of increase of opioid overdose deaths in the control states was higher than that of Washington. After 2012, a more rapid increase in the overdose deaths is seen for the control states. This rate of increase is lower for that of Washington. It can be concluded that the implementation of opioid control policies might have at least prevented the rapid increase in opioid overdose death rates, but not really reduced them.

Limitations

Both types of analyses - pre-post and difference-in-difference are vulnerable to bias. The differences in demographics, socioeconomic status, health conditions, etc. across both the experimental states (where the opioid control policies have been implemented) and the control states are not accounted for. Since there is no information on such potential confounding variables, it is hard to determine which factor is responsible for affecting the opioid overdose deaths or opioid shipments and thus be completely sure that the policy interventions have solely affected the opioid mortality or opioid shipment rates. In order to account for missing values in opioid overdose deaths and opioid shipment datasets, we imputed them. Even though the integers imputed were very small, and the number of missing observations is not substantial, some residual bias may still be introduced as the observations may not be missing at random in real life settings. Using a single value of 0 can also be somewhat arbitrary.

Conclusion

The implementation of various opioid control policies in Florida in 2010 such as mandatory registration of pain clinics, collaboration of DEA and various Florida law enforcement agencies in Operation Pill Nation, further expansion of pain clinic regulations (eg: statewide raids, seizures of assets for illegal pain clinics), have been effective in reducing opioid shipment and opioid overdose deaths. The opioid control policies implemented in Texas in 2007 - performing a patient evaluation before opioid prescription, obtaining informed consent from the patient for opioid treatment, conducting periodic review of the opioid treatment, maintaining a complete medical record of the patient's treatment - however have not been effective enough in reducing opioid overdose mortality. Similarly, the opioid control policies implemented in Washington in 2012 such as mandating a consultation threshold for adults (120 mg MED/day (oral)), or documentation of mandatory consultations, have not been effective enough in reducing opioid overdose mortality. However, they have reduced opioid shipment. Thus, the Florida state legislature should continue to implement their opioid control policies since they have been very effective in reducing both opioid shipment and opioid mortality. However, the legislatures of both Texas and Washington need to update their opioid control policies, so that they can more effectively target the reduction in opioid shipment and opioid mortality.

References

[1] Mortality Statistics:
https://www.dropbox.com/s/kad4dwebr88l3ud/US_VitalStatistics.zip?dl=0

[2] Rich, Steven, et al. “How to Download and Use the DEA Pain Pills Database.” *The Washington Post*, WP Company, 3 Sept. 2019, https://www.washingtonpost.com/national/2019/07/18/how-download-use-dea-pain-pills-database/?arc404=true.

[3] US Census Data: https://data.census.gov/