Technical Report

Effects of Policy Changes on Opioid Transactions and Mortality in the States of Florida, Texas and Washington

Authors: Vishaal Venkatesh, Abhiraj Vinnakota, Roderick Whang

1. Motivation for the project:

Over the past two decades, the United States has seen a tremendous increase in the use and abuse of prescription opioids. As a result, there has been a rise in drug overdose deaths from prescription as well as non-prescription opioids like heroin and fentanyl. Owing to this, several states such as Florida (2010), Texas (2007) and Washington (2011) have passed laws to make the prescription of opioid drugs more stringent. Assessing the effectiveness of these policy changes can be of vital importance for the respective states for course correction in this area as well as serve as guidelines for other states who may want to act on the issue of opioid regulations. To get a good understanding of the impact of the policy change, we would want to observe the patterns in opioid prescriptions as well as mortality in regard to drug overdoses. Our interest in examining mortality as well as opioid prescriptions comes from the fact that while restricting access to opioids may reduce the likelihood that future patients will end up addicted to opioids, it may drive already addicted patients to turn to alternative forms of opioids, be those illegally purchased prescription drugs, heroin, or fentanyl. This possibility is deeply troubling because the likelihood of overdosing on these illegal drugs is much higher than overdosing on regulated prescription drugs.

2. Motivation for the design of the project:

This project aims to answer a causal question. The most standardized approach to study the effect of policy change is a ‘pre-post analysis’. In this technique one looks at the trend/data of the metric of interest before and after a certain change has occurred - hoping to understand the impact of that change on the metric. This technique attributes the difference in trends entirely to the change that has been implemented; in this case the change in policy.

A better approach compared to the ‘pre-post analysis’ is the ‘difference-in-difference’ analysis where we even take into consideration the trends of the metric of interest in the control population (where the change hasn’t occurred) and compare it with the trends in the

treated population (where the change has occurred). This technique is far better in controlling for other factors that may have caused fluctuations in the metric of interest apart from the change being studied. For out study, we will be conducting both a 'pre-post' analysis as well as the 'difference-in-difference' analysis for the 3 states under consideration (Florida, Washington and Texas). The control group for the analysis will be all other 47 states where the policy changes haven't been made. This gives us the maximum statistical power in the analysis.

The scope of the analyses on both the opioid transactions and the mortality arising from drug overdoses have been summarised in the following tables:

State	Policy change year	Time period of analysis	Level
Florida	2010	2006 - 2012	Yearly

Table 1. Description of the scope of analysis for opioid transactions in Florida.

For the opioid transaction data, the states of Texas and Washington had only one year prior to the policy change and one year post the policy change respectively. This made analysis at a yearly level not very informative. Breaking this analysis down to the month level wasn't very useful either as we were still capturing some yearly trends. Therefore, a simple percent increase/decrease in the per-capita opioid transactions of Texas and Washington were calculated and was compared with the average percent increase/decrease in the per-capita opioid transactions of all other (47 non-policy) states.

State	Policy change	Time period of analysis	Method
Texas	2007	2006 - 2012	Percent Increase
Washington	2011	2006 - 2012	Percent Increase

Table 2. Description of the scope of analysis for opioid transactions in Texas and Washington.

State	Policy change year	Time period of analysis	Level
Florida	2010	2004 - 2015	Yearly
Texas	2007	2004 - 2015	Yearly
Washington	2011	2004 - 2015	Yearly

Table 3. Description of the scope of analysis for drug overdose mortality in Florida, Texas and Washington.

3. Data Sources & Transformations:

There were three main sources of data that were used in this analysis:

Opioid Transactions: The data on the county-wise transaction of drugs was obtained from the extensive database maintained by The Washington Post[1]. This dataset essentially tracks every opioid pill (hydrocodone or oxycodone) from the manufacturer to the pharmacy at a transaction (including the date on which the transaction occurred) level. Naturally, this dataset also included details on the location of the seller at the county level, date of transaction, volume of drug transaction, the Milligram Morphine Equivalent (a conversion factor based on the opioid Morphine), buyer location at the county level etc. Overall, this dataset was very comprehensive with data on over 180 million transactions between 2006-12 and was used to calculate per-capita opioid transactions in conjunction with the population dataset.

Transformations: The final dataset used for plotting the trends for opioids analysis is mentioned below:

County	State	Month	Year	opioids_per_capita	pre_post	policy_state

Table 4. General template of the final dataset used for opioid transactions.

The data related to the buyer was used to identify the county and the state. The month and the year columns were extracted from the date of transaction. The quantity of opioids was calculated as the product of the 'calc_base_wt_in_gm' and the 'MME_conversion_factor' columns. This data was collapsed at a 'State, 'County and 'Year' level for the state of Florida and at a 'State, 'County, 'Year' and 'Month' level for the states of Washington and Texas, leading to 2 different datasets. The column 'pre_post' and 'policy_state' were created considering the state under analysis, leading to 3 different datasets, one for each state. The population data was merged to these datasets and the 'opioids_per_capita' was calculated. It is important to mention that there were certain counties in a few states where the transactions of opioids were not substantial enough to be reported in the dataset. These counties were dropped in the analysis.

Drug Overdoses: This is another comprehensive dataset maintained by the US Centers for Disease Control and Prevention (CDC) under its National Vital Statistics System[2]. This serves as a record for the number of deaths by county at a yearly level. The dataset also classifies death based on the cause of death. We are concerned only with the death caused due to drug overdoses to calculate mortality arising from drug overdoses. It also has to be noted that the dataset does not include the name of the exact drug involved in a death. Hence, this data is just a proxy to measure opioid related deaths.

Transformations: US Vital Statistics data sets (.txt) were separated by year, we combined all the data sets into one file. After concatenating 12 txt files, we split the name of 'County' into 'County' and 'State' (e.g. Autauga County, AL->AL Baldwin County). Then, we removed non-unseful columns and rows with missing values and change the data types (e.g. string data to numeric data). We primarily focused on number death by 'Drug poisonings (overdose) Unintentional (X40-X44)', 'Drug poisonings (overdose) Undetermined (Y10-Y14)', 'Drug poisonings (overdose) Suicide (X60-X64)'. We merged this dataset with the population data on 'State' and 'County'. We calculated 'Death_Rate' by dividing 'Death' by 'pop2010'. We then added 'Policy State' column to indicate the states where changed the policy and 'Post' column to indicate the timeline that before and after the policy in effective.

In addition to the final dataset, there will be 3 sub datasets for each state (TX, FL, WA) under consideration for the 3 states of study, especially for Difference-in-Difference between 3 states and non-policy states. The final dataset would have the following columns.

State	County	Year	Death_Rate	Policy_State	Pre_post

Table 5. General template of the final dataset used for opioid mortality analysis.

Population: This dataset contains data on the US population at a county level[3]. It has to be noted that the US census is taken once in ten years – with the last one being in 2010. The population for the year 2010 was the most relevant to this analysis as it was the closest to the years under consideration. We chose to use the population for 2010 for all the years under consideration as using rate of change of population assumes a linear rate of increase and may

not be ideal for all the counties. This made using 2010 population data throughout, more reasonable.

Transformations: We were trying to find every year population data, but we could find only partial population data. So, we decided to use 2010 population data for 50 states and apply to 2006-2015 US Vital Statistics data sets, because the population for the year 2010 will be the most relevant to this analysis as it is the closest to the years under consideration.

4. Analysis & Interpretation:

Florida (Jan 1st, 2010)

Opioids Analysis:

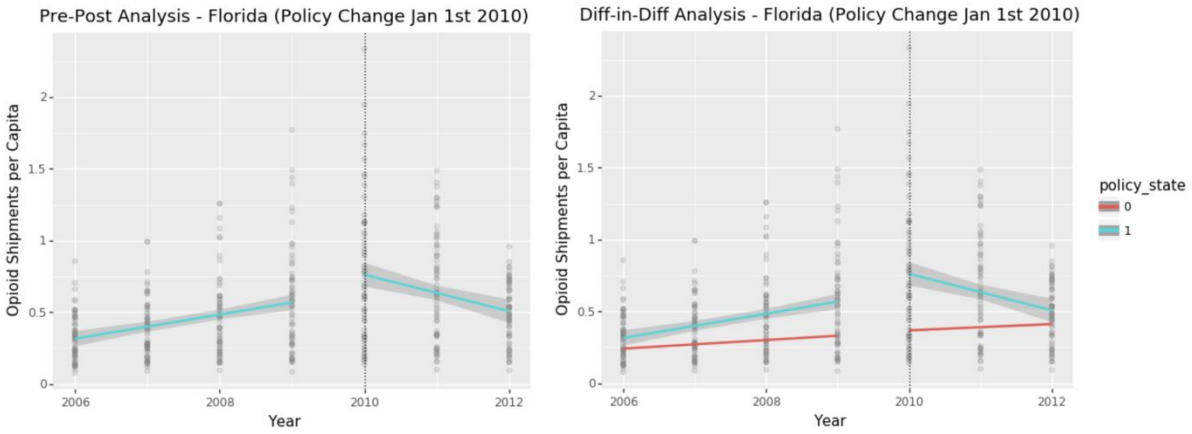

Figure 1. Pre-post and difference in difference analysis for opioid analysis in Florida.

The pre-post analysis definitely suggests a sharp change in trend of opioid prescriptions after the policy change. The trend can definitely be attributed to policy change after looking at diff-in-diff plot as we see that the trend in opioid shipments for the non-policy states does not change over time.

Mortality Analysis:

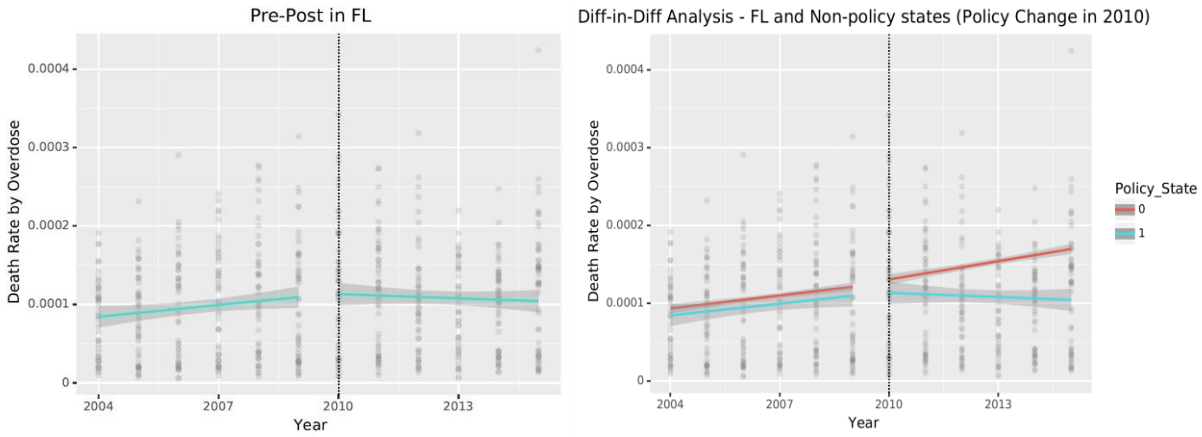

Figure 2. Pre-post and difference in difference analysis for drug morality analysis in Florida.

From the pre-post analysis, the death rate due to drug overdose was increasing steadily before the policy change went into effect in 2010. Since then, the death rate has been a slightly decreasing trend. The diff-in-diff analysis helps in attributing the change in trend to the policy change.

Texas (Jan 1st, 2007)

Opioids Analysis:

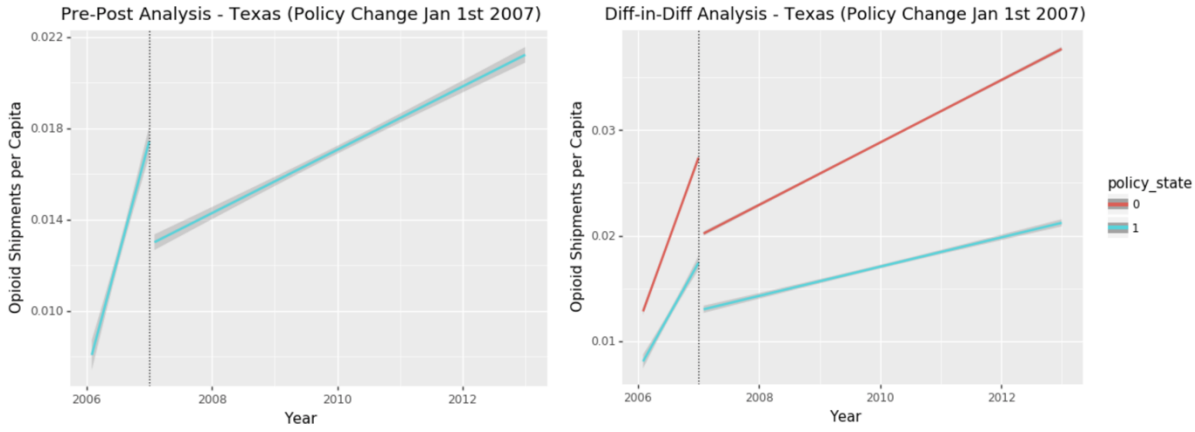

Figure 3. Pre-post and difference in difference analysis for opioid analysis in Texas.

At the first glance, though the pre-post analysis suggests that the rate of increase in opioid shipments decreased after the policy change, the diff-in-diff analysis seems to suggest a similar decrease across the non-policy states as well, which seemed strange.

Upon digging deeper, we saw that the 'pre' part of both the plots did not have enough data to show the trend across years, rather, it was capturing a yearly trend. This was conclusive when we plotted the yearly trend across several years, as can be seen from below.

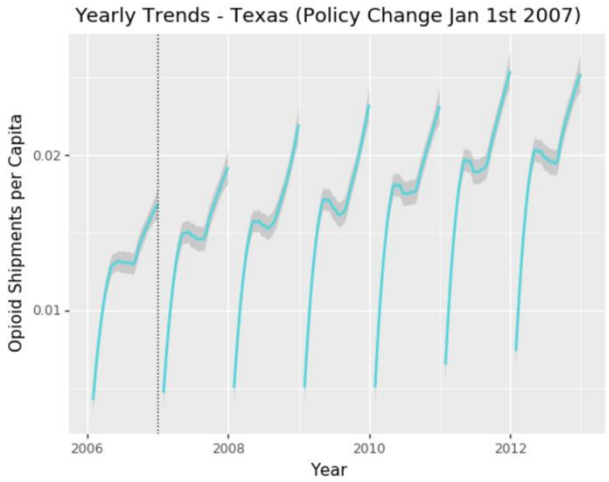

Figure 4. Yearly trends in Texas – instead of showing trend across years .

Since, comparing a yearly trend in 'pre' with a year over year trend in 'post' time period wasn't the correct way of analysis, we resorted to taking the average of the 'opioids_per_capita' across counties at a month level separately for the 'pre-post'periods and viewed it across 'policy_state'. The results are mentioned below:

Texas			
pre_post	**policy_state**		
	0	**1**	
pre	0.020123	0.012768	
post	0.028964	0.017118	
% increase	43.93%	34.07%	**9.87%**

Table 6. Pre and Post percent increase in opioids per capita in the state of Texas.

We see that though the opioid shipments per county per month per capita have largely on an average increased in the 'post' period when compared to the 'pre' period across all states. However, the %increase in Texas was approximately 10% lower when compared to the rest.

Mortality Analysis:

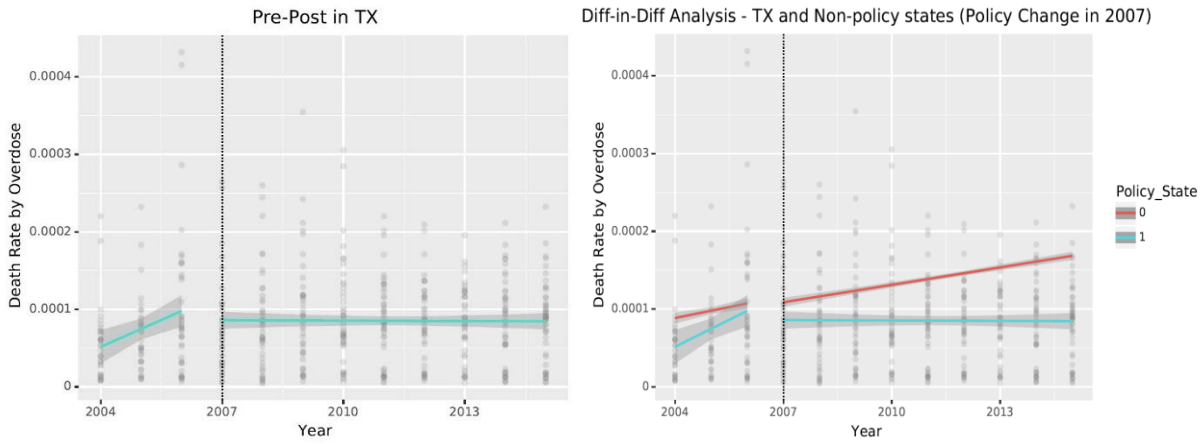

Figure 5. Pre-post and difference in difference analysis for opioid mortality in Texas.

The pre-post comparison indicates that the increase in in death rates by drug overdose has been braked by the changes in policy made in the year 2007. The 'diff-in-diff' reaffirms these conclusions.

It's interesting to note that the increase in the death rate was significantly higher in Texas in the 'pre' period when compared with the rest of the states.

Washington (Jan 1st, 2011)

Opioids Analysis:

Washington			
pre_post	**policy_state**		
	0	**1**	
pre	0.025303	0.029657	
post	0.033672	0.033169	
% increase	33.08%	11.84%	**21.23%**

Table 7. Pre and Post percent increase in opioids per capita in the state of Washington.

Upon facing similar issues as with the state of Texas, this time with the 'post' period, we went on to calculate the averages of opioids shipments per county per capita per month across a similar matrix as earlier. We can see from the above matrix that the %increase in the opioid shipments in Washington was around 21% lesser than that of non-policy states when compared between the pre and the post periods.

Mortality Analysis:

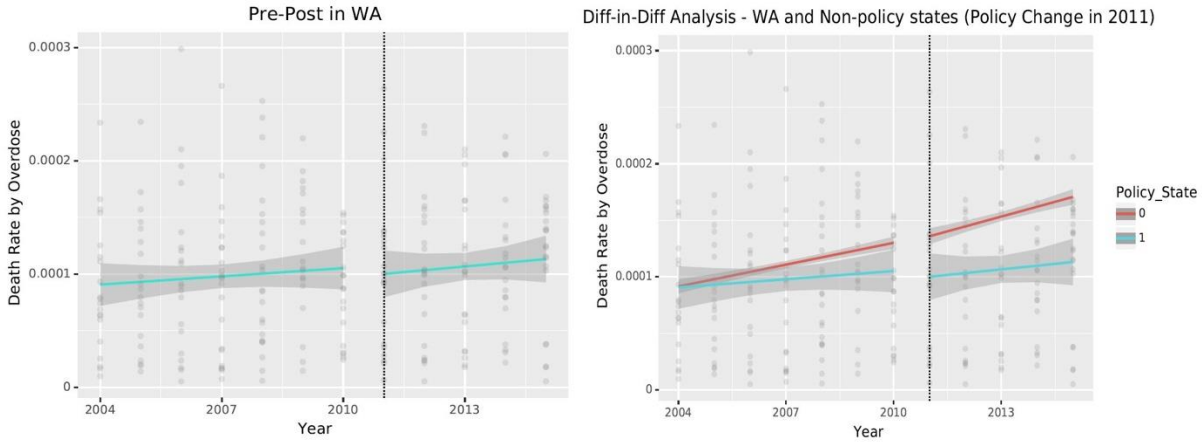

Figure 6. Pre-post and difference in difference analysis for opioid mortality in Washington.

Based on the above plots, the new policy change does not seem to be affecting the drug overdose mortality a lot. The death rates seem to be more or less increasing at the same pace more or less.

5. Limitations:

There are a couple of limitations that have to be brought to the attention. Firstly, our data on opioid transactions only contain data on transactions – who sold it and who bought it. We don't know if all the opioid transacted were dispensed – we have operated under the assumption that all the drugs transacted were sold and were sold in the same county where they were bought. Secondly, not all opioid transactions have to reported to the DEA. Only transactions exceeding a certain threshold have to be reported to the DEA as mandated by the law. This allows smaller transactions to escape the radar of the DEA and therefore making our analysis not entirely accurate. Thirdly, the dataset on drug overdose mortality contains data on all-drug related deaths – not specifically deaths related to opioid overdosing. This makes our analysis suffer slightly as we have assumed all drug-related deaths to be caused due to opioid overdosing. Fourthly, the not drug-related deaths were reported in the drug overdose mortality dataset. Again, only deaths exceeding a certain threshold (10 deaths) were reported. Finally,

insufficient data for Texas and Washington made it difficult to perform a thorough pre – post and difference in difference analysis. We had to resort to calculating percent-difference, which allowed us to gain an insight into the trends but were nevertheless a compromise.

6. Conclusion:

The overall analysis more or less seemed to be fruitful. For the states of Florida and Texas, both the opioid analysis and the drug overdose mortality analysis indicate the success of the policy changes that were made in the respective states. However, for the state of Washington, though the numbers from the opioid analysis seem promising, we cannot make similar conclusions from the mortality analysis.

Further analysis maybe carried out on the state of Washington to get to a more conclusive answer.

Report to the Policymaker

Effects of Policy Changes on Opioid Transactions and Mortality in the States of Florida, Texas and Washington

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1. **Motivation:**

Addiction to opioids is a very serious problem all around the world. What initially starts as simple cases of medically unjustified, overprescribing of painkilling opioids by physicians may quickly evolve to put millions of people at the risk of severe addiction ultimately leading to their deaths by overdose. While ostensibly it might seem that a simple change in policy to curb such rampant, careless prescriptions might be the solution to the problem – in reality, the situation is vastly more complicated. Substance abuse isn't best treated by simply restricting access to drugs/opioids. Rehabilitation is often a carefully curated program where individuals are navigated through a series of phases to relieve them of their addictions. Simply curbing the supply of opioids might result in negative outcomes - which may include but not be limited to individuals seeking out illegal, more potent opioids. This may not only result in more serious addictions, but may also increase the chances of overdosing, as some of these illegally manufactured/circulated opioids such as heroin and fentanyl are far more potent than the average painkilling opioids such as oxycodone and hydrocodone. Moreover, such illegal transactions are not tracked by the Drug Enforcement Administration (DEA), which makes it impossible to accurately determine the magnitude of the problem. This strongly suggests that any piece of legislation aiming to regulate the flow opioids into a state must carefully consider the consequences. In this analysis, we aim to study the effects of policy changes on the per capita opioid transactions and opioid mortality in three different states where policy changes were made in the recent past – Florida, Texas and Washington state. We hope this analysis will serve the future policymaker well when it comes to enacting legislations regulating the flow of opioids.

2. **Data:**

There were three main sources of data that were used in this analysis.

2.1 **Opioid Transactions:**

The data on the county-wise transaction of drugs was obtained from the extensive database maintained by The Washington Post[1]. This dataset essentially tracks every opioid pill (hydrocodone or oxycodone) from the manufacturer to the pharmacy at a transaction (including the date on which the transaction occurred) level. Naturally, this dataset also included details on the

location of the seller at the county level, date of transaction, volume of drug transaction, the Milligram Morphine Equivalent (a conversion factor based on the opioid Morphine), buyer location at the county level etc. Overall, this dataset was very comprehensive with data on over 180 million transactions between 2006-12 and was used to calculate per-capita opioid transactions in conjunction with the population dataset.

2.2 **Drug Overdoses:**

This is another comprehensive dataset maintained by the US Centers for Disease Control and Prevention (CDC) under its National Vital Statistics System[2]. This serves as a record for the number of deaths by county at a yearly level. The dataset also classifies death based on the cause of death. We are concerned only with the death caused due to drug overdoses to calculate mortality arising from drug overdoses. It also has to be noted that the dataset does not include the name of the exact drug involved in a death. Hence, this data is just a proxy to measure opioid related deaths.

2.3 **Population:**

This dataset contains data on the US population at a county level[3]. It has to be noted that the US census is taken once in ten years – with the last one being in 2010. The population for the year 2010 was the most relevant to this analysis as it was the closest to the years under consideration. We chose to use the population for 2010 for all the years under consideration as using rate of change of population assumes a linear rate of increase and may not be ideal for all the counties. This made using 2010 population data throughout, more reasonable.

The scope of the analyses on both the opioid transactions and the mortality arising from drug overdoses have been summarised in the following tables (Table 1, Table 2 and Table 3).

State	Policy change year	Time period of analysis	Level
Florida	2010	2006 - 2012	Yearly

Table 1. Description of the scope of analysis for opioid transactions in Florida.

For the opioid transaction data, the states of Texas and Washington had only one year prior to the policy change and one year post the policy change respectively. This made analysis at a yearly level not very informative. Breaking this analysis down to the month level wasn't very

useful either as we were still capturing the yearly trends and not the trends across years. Therefore, a simple percent increase/decrease in the per-capita opioid transactions of Texas and Washington were calculated and was compared with the average percent increase/decrease in the per-capita opioid transactions of all other (47 non-policy) states.

State	Policy change year	Time period of analysis	Method
Texas	2007	2006 - 2012	Percent Increase
Washington	2011	2006 - 2012	Percent Increase

Table 2. Description of the scope of analysis for opioid transactions in Texas and Washington.

State	Policy change year	Time period of analysis	Level
Florida	2010	2004 - 2015	Yearly
Texas	2007	2004 - 2015	Yearly
Washington	2011	2004 - 2015	Yearly

Table 3. Description of the scope of analysis for drug overdose mortality in Florida, Texas and Washington.

3. **Analysis and Interpretation:**

One approach to studying the effect of policy on per capita opioid transactions and drug overdose mortality is to simply look at the trends before and after the policy was enforced. If an *increasing* trend (positive slope) was observed in both per-capita opioid consumption and drug-related overdose deaths prior to the policy enactment – the lawmakers were well-justified in being alarmed and passing legislation to limit opioids flow into the state. Furthermore, if a *decreasing* trend (negative slope) was observed in both per-capita opioid consumption and drug-related overdose deaths post the policy enactment – the lawmakers were indeed very successful in circumventing a possible endemic that could have endangered millions of lives. The technical jargon for this type of analysis is known as a 'Pre – Post Analysis' and is often times very useful in gaining valuable insights into existing trends in the problem. However, this method is flawed in one major way and there are better methods to study the effects of policy change.

Let's elucidate the flaw in the above method using an analogy. Consider the case of 17-year old Jeremy Belcher that lives in Princeton, New Jersey. Unfortunately, Jeremy is dangerously obese, and his physician has decided to enforce stringent measures to bring Jeremy's weight down. For starters, Jeremy is only allowed a fluid-based diet (fruit juices, soups etc.) for a whole entire week. Jeremy has promised to stick to his new diet and is due to return in one week's time so that the doctor may check on his progress.

A week later Jeremy visits his physician, and to everybody's pleasant surprise Jeremy had lost 20 whole pounds! The doctor is pleased and deems his treatment a huge success. What the doctor did here is analogous to a simple pre – post analysis around his prescribed diet to Jeremy. What the doctor failed to realize was that Jeremy's favorite chain burger-joints that he frequents was closed for renovations that week – all 49 branches. This may have been a huge, unaccounted factor in Jeremy's progress. A simple pre – post analysis does not take such factors into account and can therefore be misleading. Instead of comparing Jeremy's progress before and after a said treatment, a more effective form of analysis would be to compare Jeremy's weight loss with that of another individual, say Ralph, who is comparable to Jeremy in terms of weight and also frequents the exact burger chain joints that Jeremy frequents. While this example might be getting unnecessarily specific to Jeremy and Princeton, New Jersey, parallels may be drawn between this analogy and the situation in Florida, Texas and Washington. While it is entirely possible that the change in policy was solely responsible for the decrease in opioid transactions and deaths, it could also very well be the case that a simultaneous federal curb on opioid flow – independent of policy changes at the state level- may have caused the desired results. This would inaccurately suggest that the policy change worked, while in reality it was a mere coincidence that a federal legislation was enacted at the same time as the state legislation. Analogous to comparing Jeremy with Ralph, a better technique in the case of states would be to compare the changes in, for e.g., Florida before and after policy change with another state similar to Florida before and after the policy change. Even better and statistically stronger is to compare Florida with all other 47 states where a policy was not enacted (All states excluding Washington, Texas and obviously Florida itself). This would eliminate the effects all the states were commonly subjected to at the time and help us isolate and study the effect of the policy on the policy state. In statistics, this technique is called the Difference-in-Difference method.

Following is an analysis of the opioid transactions and drug overdose mortality for each of the policy states - Florida, Washington and Texas. In Texas (Figure 1),

3.1 Florida (Jan 1st, 2010)

3.1.1 Opioids Analysis:

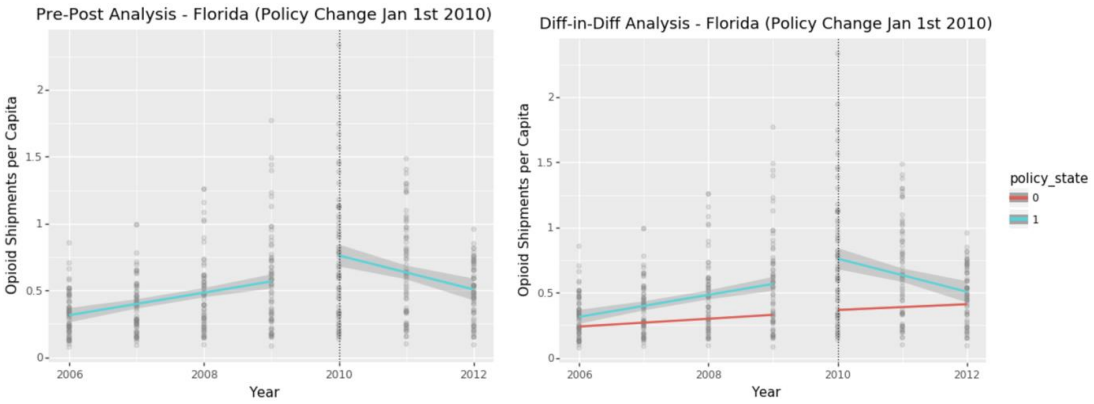

Figure 1. Pre-post and difference in difference analysis for opioid analysis in Florida.

The pre-post analysis definitely suggests a sharp change in trend of opioid prescriptions after the policy change. The trend can definitely be attributed to policy change after looking at diff-in-diff plot as we see that the trend in opioid shipments for the non-policy states does not change over time.

3.1.2 Mortality Analysis:

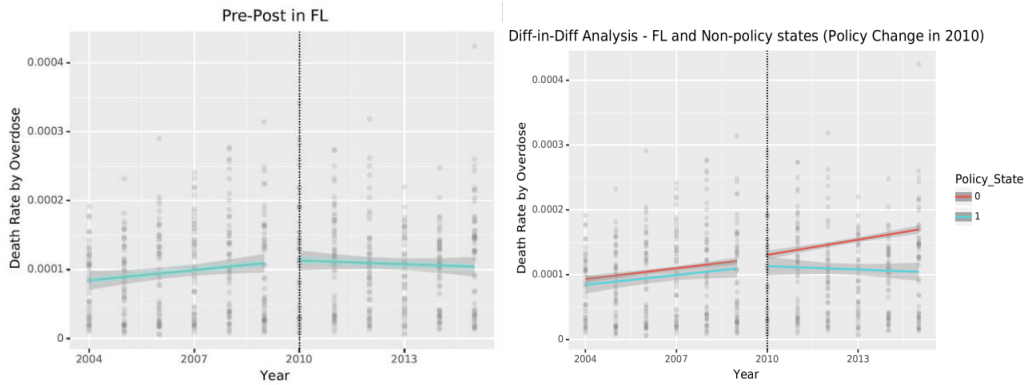

Figure 2. Pre-post and difference in difference analysis for drug morality analysis in Florida.

From the pre-post analysis, the death rate due to drug overdose was increasing steadily before the policy change went into effect in 2010. Since then, the death rate has been a slightly decreasing trend. The diff-in-diff analysis helps in attributing the change in trend to the policy change.

3. 2 Texas (Jan 1st, 2007)

3. 2. 1 Opioids Analysis:

As mentioned earlier, comparing a yearly trend in 'pre' with a year over year trend in 'post' time period wasn't the correct way of analysis, we resorted to taking the average of the 'opioids_per_capita' across counties at a month level separately for the 'pre-post'periods and viewed it across 'policy_state'. The results are mentioned below:

Texas			
pre_post	**policy_state**		
	0	**1**	
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post	0.028964	0.017118	
% increase	43.93%	34.07%	**9.87%**

Table 4. Pre and Post percent increase in opioids per capita in the state of Texas.

We see that though the opioid shipments per county per month per capita have largely on an average increased in the 'post' period when compared to the 'pre' period across all states. However, the %increase in Texas was approximately 10% lower when compared to the rest.

3.2.2 Mortality Analysis:

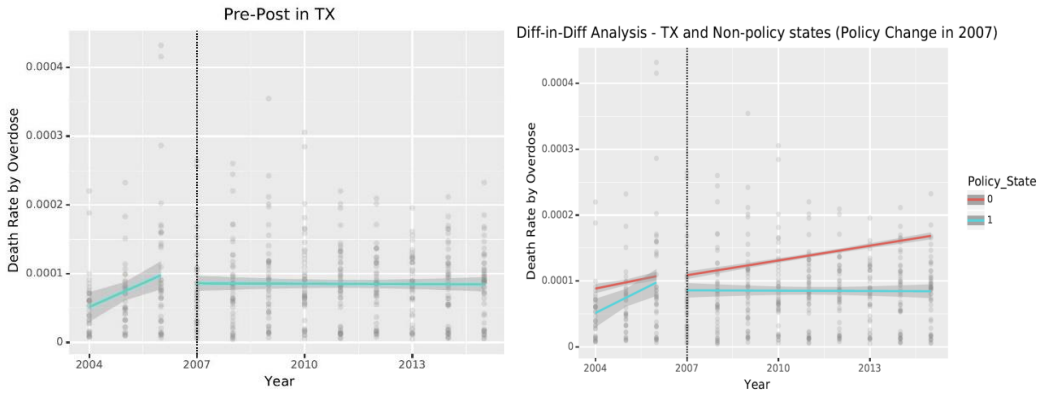

Figure 3. Pre-post and difference in difference analysis for opioid mortality in Texas.

The pre-post comparison indicates that the increase in in death rates by drug overdose has been braked by the changes in policy made in the year 2007. The 'diff-in-diff' reaffirms these conclusions. It's interesting to note that the increase in the death rate was significantly higher in Texas in the 'pre' period when compared with the rest of the states.

3.3 Washington (Jan 1st, 2011)

3.3.1 Opioids Analysis:

Washington			
pre_post	**policy_state**		
	0	**1**	
pre	0.025303	0.029657	
post	0.033672	0.033169	
% increase	33.08%	11.84%	**21.23%**

Table 5. Pre and Post percent increase in opioids per capita in the state of Washington.

Upon facing similar issues to those faced when analysing Texas, this time with the 'post' period, we went on to calculate the averages of opioids shipments per county per capita per month across a similar matrix as earlier. We can see from the above matrix that the %increase in the opioid shipments in Washington was around 21% lesser than that of non-policy states when compared between the pre and the post periods.

3.3.2 Mortality Analysis:

Figure 4. Pre-post and difference in difference analysis for opioid mortality in Washington.

Based on the above plots, the new policy change does not seem to be affecting the drug overdose mortality a lot. The death rates seem to be more or less increasing at the same pace more or less.

4. **Limitations:**

Although the overall analysis was quite satisfactory, there are a couple of limitations that have to be brought to the attention of the policymaker. Firstly, our data on opioid transactions only contain data on transactions – who sold it and who bough it. We don't know if all the opioid transacted were dispensed – we have operated under the assumption that all the drugs transacted were sold and were sold in the same county where they were bought. Secondly, not all opioid transactions have to reported to the DEA. Only transactions exceeding a certain threshold have to be reported to the DEA as mandated by the law. This allows smaller transactions to escape the radar of the DEA and therefore making our analysis mostly accurate but not entirely accurate. Thirdly, the dataset on drug overdose mortality contains data on all-drug related deaths – not specifically deaths related to opioid overdosing. This makes our analysis suffer slightly as we have assumed all drug-related deaths to be caused due to opioid overdosing. Fourthly, the not drug-related deaths were reported in the drug overdose mortality dataset. Again, only deaths exceeding a certain threshold (10 deaths) were reported. Finally, insufficient data for Texas and Washington made it difficult to perform a thorough pre – post and difference in difference analysis. We had to resort to calculating percent-difference, which allowed us to gain an insight into the trends but were nevertheless a compromise. We hope lawmakers and policymakers will benefit from our analysis to enact policy for the betterment of the community.