The Impact of Opioid Control Policies

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I.   Technical Report

Motivation For Project

Beginning in the late 1990s, the United States has undergone an opioid addiction crisis, initially due to an over-prescription and over-use of painkillers, and then perpetuated by the use of illegal drugs. This has led to an increase in opioid-overdose deaths and the number of illegal drugs being shipped into the country. Policymakers in many states have tried to address these problems by implementing new legislation that attempts to limit who can prescribe opioids and control the flow of opioids from other countries as well as within the U.S. This project is motivated by the need to evaluate the effects of such policies, so other states may follow successful examples and forego attempts at implementing policies that have proven unsuccessful.

Research Design Used

We are focusing our analysis on three U.S. states: Florida, Texas, and Washington. These three states have data on opioid overdose deaths from before they implemented policy changes (Texas in 2007, Florida in 2012, and Washington in 2012) that aimed to reduce the impact of opioid addiction and data from several years after the policy took effect (up to 2014 or 2015). We are using data for opioid overdose related deaths for all three states and opioid shipment data for Florida and Washington, because Texas does not have enough data available to warrant an analysis of drug shipments over the designated timeframe.

Each of the target states will be compared to three different states that will be pooled and function as controls. Including control states will account for the possibility of policy changes on the federal level affecting the target states outside of the internal policy change. Pooling the data from the comparison states allows us to make more confident statements on how much of the differences we see before and after the state's policy changes were caused by those specific changes, rather than any effects that happened to the whole United States in the designated timeframe.

The comparison states were chosen for their known statistics on drug overdose mortality rate in 2005, based on data from the Centers for Disease Control.[1] Florida had an age-adjusted overdose death rate of 13.5, so we chose states like this rate: Arizona (14.1), Colorado (12.7) and Louisiana (14.7). Texas had an age-adjusted overdose death rate of 8.5, so the comparison states chosen for Texas are Kansas (9.1), Mississippi (8.8), and Wisconsin (9.3). For Washington, with an overdose death rate of 13, we chose Arizona (14.1), Colorado (12.7), and Oklahoma (13.8). For all target states, we aimed to include at least one state with a rate above and at least one with a rate below the target state. Additionally, all the chosen comparison states are also in relative proximity to each of the respective target states.

The second consideration for choosing the comparison states was making sure that they did not implement legislation to limit opioid prescription until after our observation period had ended (in 2014). This data was sourced from Ballotpedia[2]. We examined the pre-selected comparison states for if or when they implemented policy changes, and found that none of them implemented any within our observation period up until 2015:

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[1] https://www.cdc.gov/nchs/pressroom/sosmap/drug_poisoning_mortality/drug_poisoning.htm
[2] https://ballotpedia.org/Opioid_prescription_limits_and_policies_by_state

Arizona implemented new policy on October 24, 2016,
Colorado implemented new policy on August 1, 2017,
Kansas has not implemented any policy changes thus far,
Louisiana implemented new policy on June 12, 2017,
Mississippi has not implemented any policy changes thus far,
Oklahoma implemented new policy on May 2, 2018,
Wisconsin has not implemented any policy changes thus far.

Overview of Data Used

Overdose Death Data

The best source of national data on drug overdoses is in the U.S. Vital Statistics records. It includes data on every death in the United States. This data is collected on an annual level, so counts are per county-year.

Additional Data Necessary for Overdose Deaths

Our eventual metrics for this analysis are deaths per capita, so we needed to gather additional data that includes information about the population of each county within each state. We used a census data set found through the United States Census Bureau[3]. Each dataset we used contains ten years of data for each county, and each county's "Name" column included its associated state name. To merge the census data to the overdose death data, some string manipulation needed to be performed on the "County Name" column so it could match the primary key from the overdose death data. After merging, the overdose dataset contained the population for each observation so that overdose death per capita can be easily calculated.

Issues Related to Data Cleaning

The first problem we encountered when merging the overdose death data was that data for each year was in a different file. This was remedied by a simple for-loop over the "Year" variable to load and concatenate the files together. After a validity check for missing values, we noticed that a significant portion of counties had missing data related to overdose deaths. It was not a small enough portion to be negligible, so we imputed the missing values. Those values were determined by taking average of each state's overdose death rate for each year observed, then placing that state average into any counties of that state that had a missing value. After we were satisfied that we no longer had missing nor duplicated data, we kept only the columns for county, year, drug/alcohol induced cause, and death count.

The data from the official U.S. Census website in the 2000-2019 range was split into two ten-year time periods, and the data for each state was stored in separate files. After manually downloading each target state's data, we found that each file contained several documentation rows and columns that were not of interest to this analysis, such as income summary. To remove this superfluous information, we wrote automated scripts to modify the data format in these files and o only leave county, state, and year observations. And because each of the two ten-year period data sets were in different formats from each other (XLS and XLSX), we had to have two functions to address both formats.

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[3]https://urldefense.com/v3/__http://Census.gov__;!!OToaGQ!6efKOCd1I6x8GrQkrOtL9p43O7hmlmrdAbUPGypskBl4AfSKO-IQoLG6cJTu3jPAfj7tMQ$

Drug Shipment Data

The Washington Post sifted through nearly 500 million transactions from 2006 through 2014 that are detailed in the Drug Enforcement Administration's (DEA) database and analyzed shipments of oxycodone and hydrocodone pills, which account for three-quarters of the total opioid poll shipments to pharmacies. The Post has made this data available at the country and state levels to help the public understand the impact of years of prescription pill shipments on their communities. The entire data set is a large TSV file that is greater than 80 GB containing 43 measured variables.

Issues Related to Data Cleaning

We imported the data by separating it by each state, operating on the data for the states we needed (selecting only the necessary variables), then concatenating the files back together. For Florida, Washington, and their associated comparison states, we selected data based only on those necessary variables: the buyer's state and county, the shipment date, and a variable to represent the quantity of the opioid shipment. This last variable was calculated using Morphine Milligram Equivalent (MME) multiplied by the total weight of the drug (active weight of the drug in grams). Additionally, we had to change the format of the transaction date into a date-time variable, and then extracted just the year from that value.

When we performed a validity check, we discovered some duplicate values, which were discarded. We also found that Florida had three missing counties. Because this is such a small amount of missing data, and specific only to one of our target states, it is negligible, and we dropped those observations as well.

Finally, the data frame was grouped by county and year level (identical to our overdose death and population data). The quantity of the opioid shipment was calculated, naming the result "MME", and the data was subset for the last time using variables that we wanted to keep for merging. The merge was achieved via a function concatenating the data sets together and merging them to the death-rate-population data set.

Summary statistics

Below are charts summarizing overall statistics for overdose deaths and drug shipments for each of the target states and their corresponding comparison states.

Summary Statistics for Opioid Overdose Deaths per Capita

	Washington	Comparison States	Florida	Comparison States	Texas	Comparison States
Count	367	890	651	909	1,323	1,229
Mean	0.0084	0.0074	0.010	0.0078	0.0041	0.0043
Standard Deviation	0.0068	0.0095	0.0085	0.0092	0.0058	0.0065
Minimum	0	0	0	0	0	0
25th Q	0	0	0	0	0	0
Median	0.0097	0	0.011	0.0062	0	0
75th Q	0.012	.014	0.016	0.014	0.0079	0.0089
Maximum	0.031	.078	0.041	0.078	0.043	0.047

The lowest number of reported deaths was in Texas, while Florida had the highest number of deaths related to opioid overdoses, which may reflect the number of citizens in these states. The averages for our target states and the comparisons are quite similar, which makes us more confident in our selection.

Summary Statistics for Opioid Shipments (in MME) per Capita

	Washington	Comparison States	Florida	Comparison States
Count	2,088	3,234	3,108	3,306
Mean	72,250	123,911	21,5032	107,225
Standard Deviation	97,163	241,579	328,724	219,794
Minimum	1.17	0.37	63	0.37
25th Q	13,487	25,349	52,036	25,056
Median	36,288	47,868	109,195	51,402
75th Q	81,935	95,034	235,774	96,774
Maximum	601,350	2,657,081	3,302,571	2,657,081

The mean number of opioid shipments in Washington and Florida were lower than their comparison states, which may be relevant to our analysis. While Florida had the lowest number of shipments on average, it also had the highest maximum.

Overdose Death Rate Analysis
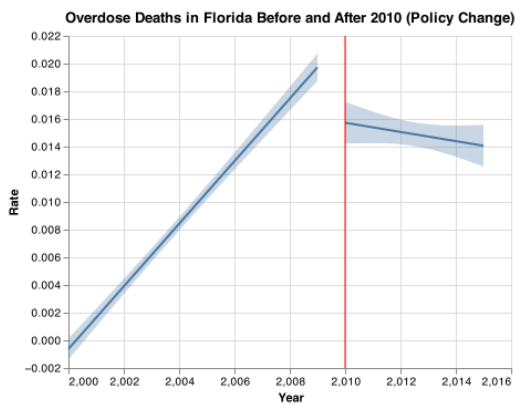
Pre-Post Comparison
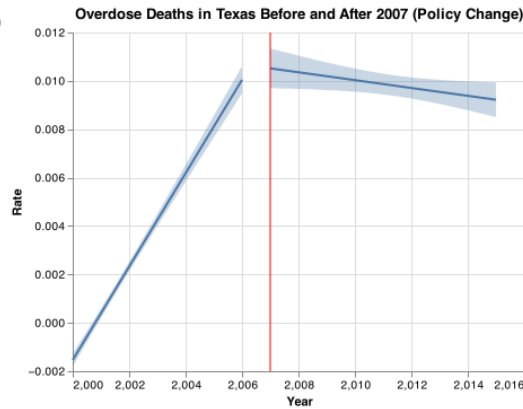

Figure 1: Florida before and after 2010

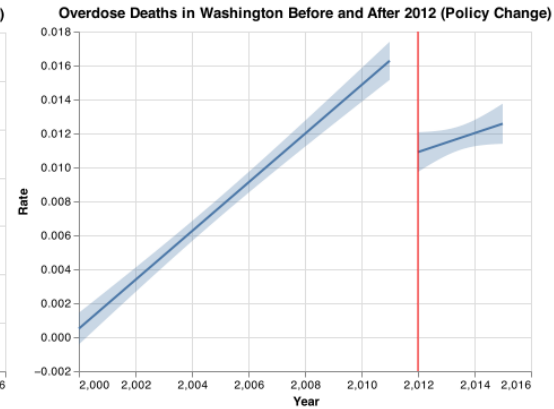Figure 2: Texas before and after 2007

Figure 3: Washington before and after 2012

Interpretation

The rate of opioid related overdose deaths in Florida was increasing steeply between the years of 2000 and 2010, when the policy change was implemented, then was on a shallower decline until 2015. In Texas, we see that the rates of overdose death are on the whole lower than in Florida but has a slightly steeper incline during its increase until 2007. After the policy change, it declines but at an even shallower rate than in Florida. Washington has overall overdose death rates in between Texas and Florida, and has a slightly shallower increase rate, but its policy change does not seem to have changed its trend. The overdose death rate did drop about five units, which is the largest drop among the three states, but its trend is still drives upward after the policy implementation. These analyses overall appear to show effectiveness in the policy changes in curbing opioid overdose death rate trends in Florida and Texas, and number of deaths (but not trend) in Washington.

Of course, there could be potential confounding variables that we could not account for in these analyses. Examples of these possible outside variables could be nation-wide policy changes, local-level campaigns against opioids, national or global commerce changes that could affect shipments, or any such similar variables. Because we cannot account for these confounding variables in a strictly pre-post comparison analysis, we can also implement a difference-in-difference analysis. This type of analysis allows us to control for effects cannot account for, such as a national policy change.

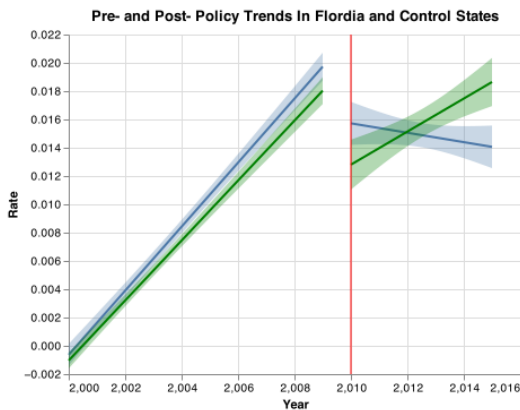*Difference-in-Difference Comparison*

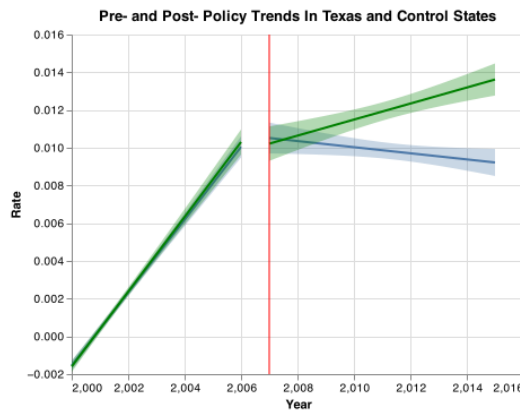Figure 4: Florida (blue) and pooled comparison states (green), before and after 2010

Figure 5: Texas (blue) and pooled comparison states (green), before and after 2007
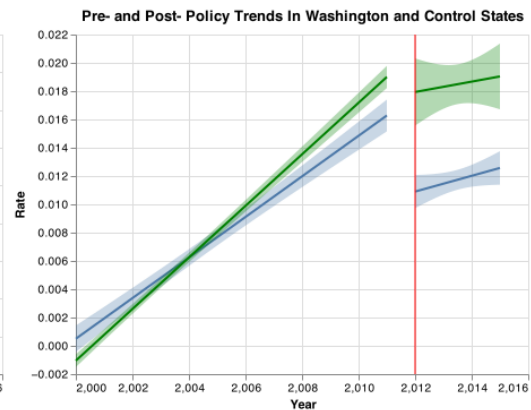
Figure 6: Washington (blue) and pooled comparison states (green), before and after 2012

Interpretation

It appears the policy implementation was effective in Florida when plotted against its comparison states of Arizona, Colorado, and Louisiana. Both groups dropped in overdose death rate after 2010, but while the control states had an increasing trend, Florida kept decreasing after the policy change. Texas shows a similar pattern with its comparison states of Kansas, Mississippi, and Wisconsin – both groups had steep, increasing trends in death rate, but Texas pivots to a downward trend after 2007 whereas the control states still increase, albeit at a lower rate than before Texas's policy change. Washington, on the other hand, did not see any change in trend after its policy change. Again, we see (as we did in the previous analysis) that the number of deaths did drop significantly, but overall, the trend of death rate stayed increasing, just like its comparison states of Arizona, Colorado, and Oklahoma.

Overall, this difference-in-difference analysis further confirms the findings in the pre-post analysis. Confounding variables, at least on a nation-wide scale, have been controlled for, and we see that policy implementation in Florida and Texas was effective at changing the trend of death rates, whereas post-policy Washington dropped in deaths, but the death rate is still increasing.

Opioid Shipment Rate Analysis

Note: These analyses were performed on monthly data, rather than yearly data like the overdose death analyses.
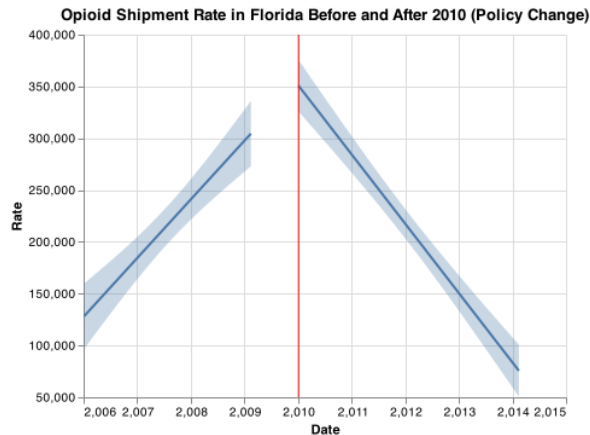
Pre-Post Comparison

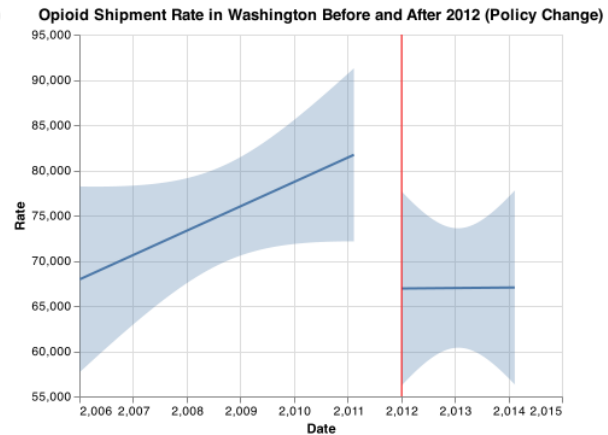Figure 7: Washington opioid shipments before and after 2012

Figure 8: Florida opioid shipments before and after 2010

Interpretation

Opioid shipments in Florida were increasing in the years before the policy change and started a steep, decreasing trend after the change. Shipments into Washington were not increasing quite as drastically as they were in Florida, nor did they achieve the decreasing trend Florida saw. Washington did drop its number of shipments coming in after 2012 but shows a somewhat constant trend until 2014.
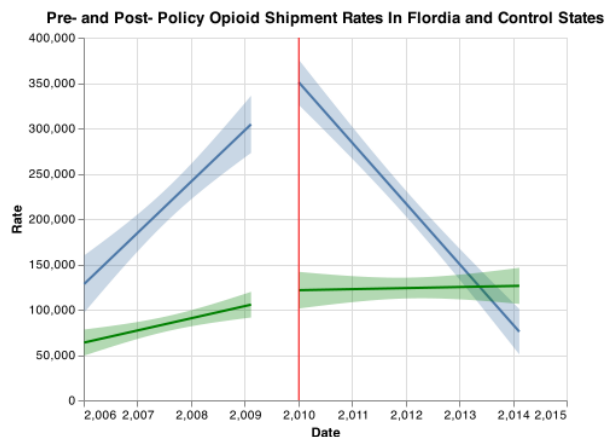
Difference-in-Difference Comparison

Figure 9: Florida (blue) and pooled comparison states (green) before and after 2010
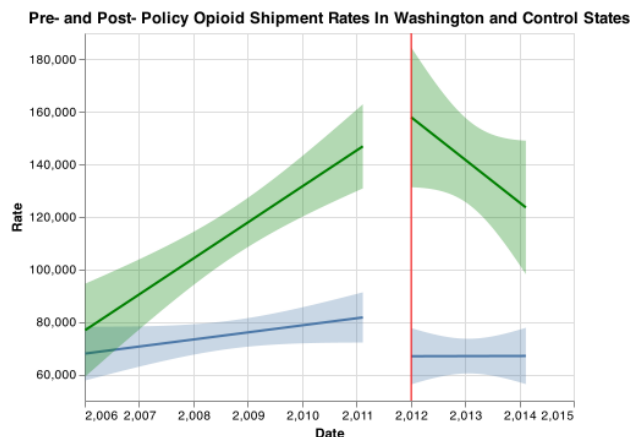

Figure 10: Washington (blue) and pooled comparison states (green) before and after 2012

Interpretation

Florida had a very steep incline in opioid shipment rates before it changed its policies, then saw a clear decline, while its comparison states continued to see increasing shipment rates, which indicates that the policy change in Florida was successful in curbing opioid shipments.

In Washington, the data is not as clear as this, since shipment rates level out but do not show the clear decline that its comparison states saw in the same timeframe. There may be factors at play in Washington that were not considered in our analysis, which may have set it apart from the three comparison states selected. For example, migration within the U.S. of people who were prescribed opioids in Washington instead of other states, a difference in population composition (perhaps there is a greater number of elderly people in Washington that require opioid prescriptions, moving a drug from a lower to a higher tier in the DEA schedule[4]). With regard to Washington's comparison states, there was a national trend that reflected the levelling out in opioid prescriptions after two major papers raised awareness in the medical community in 2009 and 2010[5] [6], and there was a 13.1% decline in prescriptions nationally between 2012 and 2015[7], which may be what is reflected in the decline in shipments in Washington's comparison states.

Limitations

It is important to keep in mind that while analyzing the outcomes of policy changes on a state level is relevant, a useful addition would be to complete the same analyses on a national level in order to tease out more general versus local effects. There are many strategies that can be and have been adopted, including raising awareness in the medical community over opioid prescriptions, which may affect opioid shipments to pharmacies more than a policy change might; or there could be changes to drug enforcement policies or to opioid buyback programs[8].

In addition, this data is solely focused on the U.S. and several of its states, but it could be relevant to take into account how illicit drug use might be fueled by changes in policies in our neighboring countries, like Canada, Mexico, Central America, and South America.

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[4] Fulton-Kehoe, Deborah PhD; Lofy, Kathryn H. MD; Le, Vi MS; Sterling, Ryan PhD; Sears, Jeanne M. PhD; Franklin, Gary MD Opioid-Prescribing Metrics in Washington State: Trends and Challenges, Journal of Public Health Management and Practice: May/June 2020 - Volume 26 - Issue 3 - p 214-221 doi: 10.1097/PHH.0000000000001149

[5] Chou et al., Clinical Guidelines for the Use of Chronic Opioid Therapy in Chronic Noncancer Pain, J Pain. 2009 February ; 10(2): 113–130. doi:10.1016/j.jpain.2008.10.008.

[6] The Management of Opioid Therapy for Chronic Pain Working Group, VA/DoD CLINICAL PRACTICE GUIDELINE FOR MANAGEMENT OF OPIOID THERAPY FOR CHRONIC PAIN, Department of Veterans Affairs Department of Defense, United States Army MEDCOM Final Draft 306-1

[7] Guy GP Jr., Zhang K, Bohm MK, et al. Vital Signs: Changes in Opioid Prescribing in the United States, 2006–2015. MMWR Morb Mortal Wkly Rep 2017;66:697–704. DOI: http://dx.doi.org/10.15585/mmwr.mm6626a4

[8] Soelberg CD, Brown RE Jr, Du Vivier D, Meyer JE, Ramachandran BK. The US Opioid Crisis: Current Federal and State Legal Issues. Anesth Analg. 2017 Nov;125(5):1675-1681. doi: 10.1213/ANE.0000000000002403. PMID: 29049113

II.   *Policymaker Report*

Motivation for project

Beginning in the late 1990s, the United States has undergone an opioid addiction crisis, initially due to an over-prescription and over-use of painkillers, and then perpetuated by the use of illegal drugs. This has led to an increase in opioid-overdose deaths and the number of illegal drugs being shipped into the country. Policymakers in many states have tried to address these problems by implementing new legislation that attempts to limit who can prescribe opioids and control the flow of opioids from other countries as well as within the U.S. This project is motivated by the need to evaluate the effects of such policies, so other states may follow successful examples and forego attempts at implementing policies that have proven unsuccessful.

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The second consideration for choosing the comparison states was making sure that they did not implement legislation to limit opioid prescription until after our observation period had ended (in 2014). This data was sourced from Ballotpedia[10]. We examined the pre-selected comparison states for if or when they implemented policy changes, and found that none of them implemented any within our observation period up until 2015:

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Overview of Data Used

Overdose Death Data

The best source of national data on drug overdoses is in the U.S. Vital Statistics records. It includes data on every death in the United States. This data is collected on an annual level, so counts are per county-year.

Additional Data Necessary for Overdose Deaths

Our eventual metrics for this analysis are deaths per capita, so we needed to gather additional data that includes information about the population of each county within each state. We used a census data set found through the United States Census Bureau[11].

Drug Shipment Data

The Washington Post sifted through nearly 500 million transactions from 2006 through 2014 that are detailed in the Drug Enforcement Administration's (DEA) database and analyzed shipments of oxycodone and hydrocodone pills, which account for three-quarters of the total opioid poll shipments to pharmacies. The Post has made this data available at the country and state levels to help the public understand the impact of years of prescription pill shipments on their communities.

Overdose Death Rate Analysis

To visualize the changes in opioid related deaths before and after the policy changes, plots were created to show the trends before and after the policy changes in each of the three states of interest (*Figure 1*).
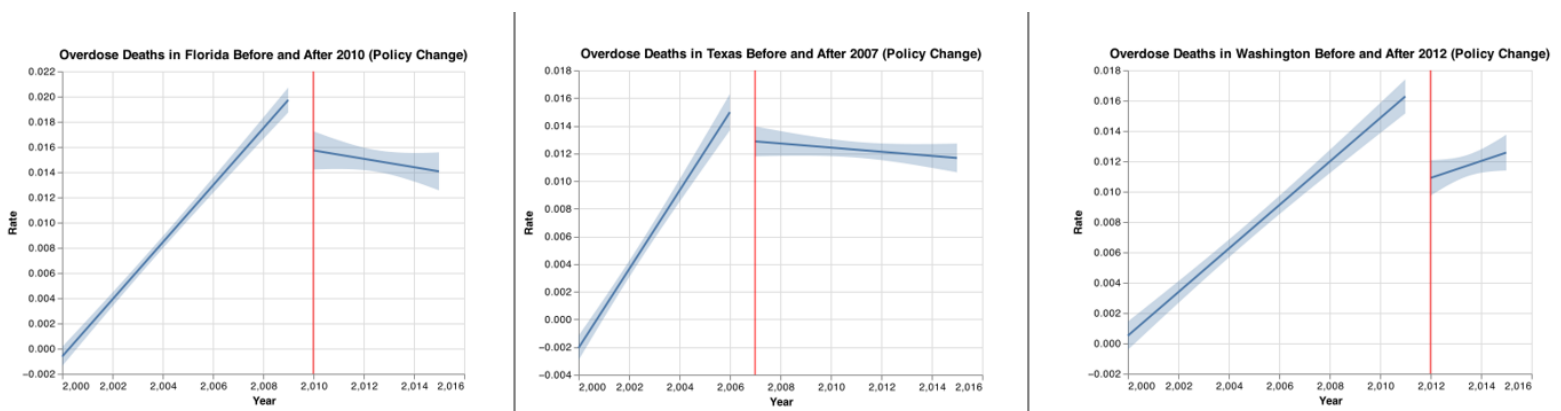

Figure 1: Overdose death rates in Florida, Texas, and Washington before and after their respective policy changes (marked by vertical red line), including 95% confidence interval bands.

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[11]https://urldefense.com/v3/__http://Census.gov__;!!OToaGQ!6efKOCd1I6x8GrQkrOtL9p43O7hmImrdAb
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The rate of opioid related overdose deaths in Florida was increasing steeply between the years of 2000 and 2010, when the policy change was implemented, then was on a shallower decline until 2015. In Texas, we see that the rates of overdose death are overall lower than in Florida but has a slightly steeper incline during its increase until 2007. After the policy change, it declines but at an even shallower rate than in Florida. Washington has overall overdose death rates in between Texas and Florida, and has a slightly shallower increase rate, but its policy change does not seem to have changed its trend. The overdose death rate did drop about five units, which is the largest drop among the three states, but its trend is still drives upward after the policy implementation. These analyses overall appear to show effectiveness in the policy changes in curbing opioid overdose death rate trends in Florida and Texas, and number of deaths (but not trend) in Washington.

Of course, there could be potential confounding variables that we could not account for in these analyses. Examples of these possible outside variables could be nation-wide policy changes, local-level campaigns against opioids, national or global commerce changes that could affect shipments, or any such similar variables. Because we cannot account for these confounding variables in a strictly pre-post comparison analysis, we can also implement a difference-in-difference analysis. This type of analysis allows us to control for effects cannot account for, such as a national policy change.
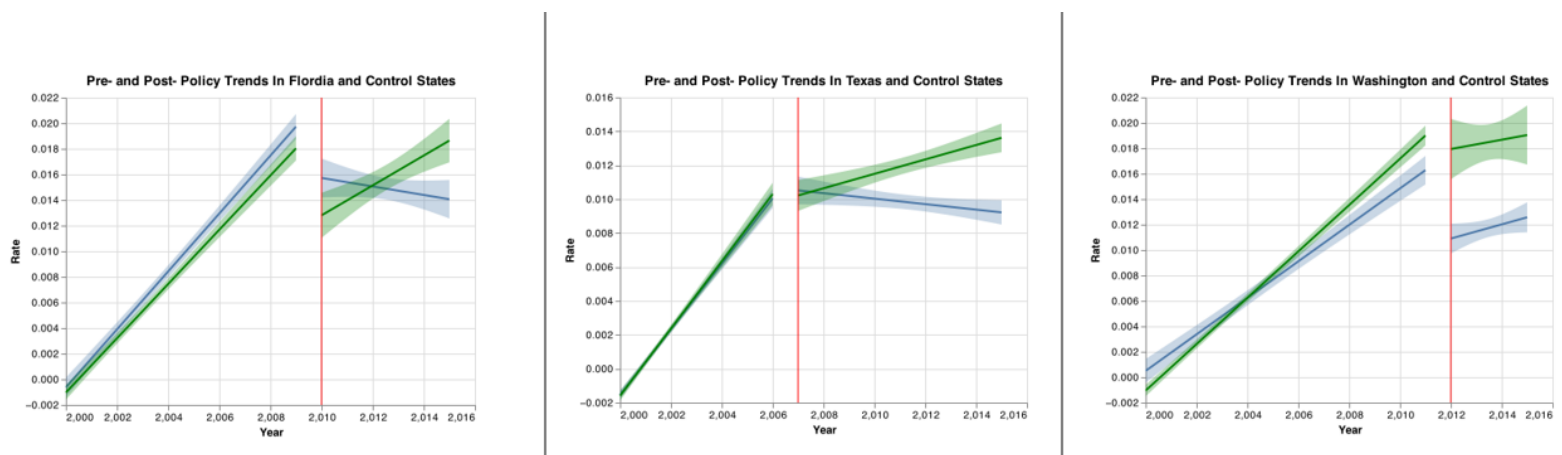

Figure 2: Overdose death rates in each of the target states compared to the pooled comparison states, before and after policy changes. Target states in BLUE, comparison states in GREEN.

It appears the policy implementation was effective in Florida when plotted against its comparison states of Arizona, Colorado, and Louisiana. Both groups dropped in overdose death rate after 2010, but while the control states had an increasing trend, Florida kept decreasing after the policy change. Texas shows a similar pattern with its comparison states of Kansas, Mississippi, and Wisconsin – both groups had steep, increasing trends in death rate, but Texas pivots to a downward trend after 2007 whereas the control states still increase, albeit at a lower rate than before Texas's policy change. Washington, on the other hand, did not see any change in trend after its policy change. Again, we see (as we did in the previous analysis) that the number of deaths did drop significantly, but overall, the trend of death rate stayed increasing, just like its comparison states of Arizona, Colorado, and Oklahoma.

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Opioid Shipment Rate Analysis

Note: These analyses were performed on monthly data, rather than yearly data like the overdose death analyses.

To visualize the changes in opioid shipments before and after the policy changes, plots were created to show the trends before and after the policy changes in each of the three states of interest and in their comparison states (*Figure 3*).
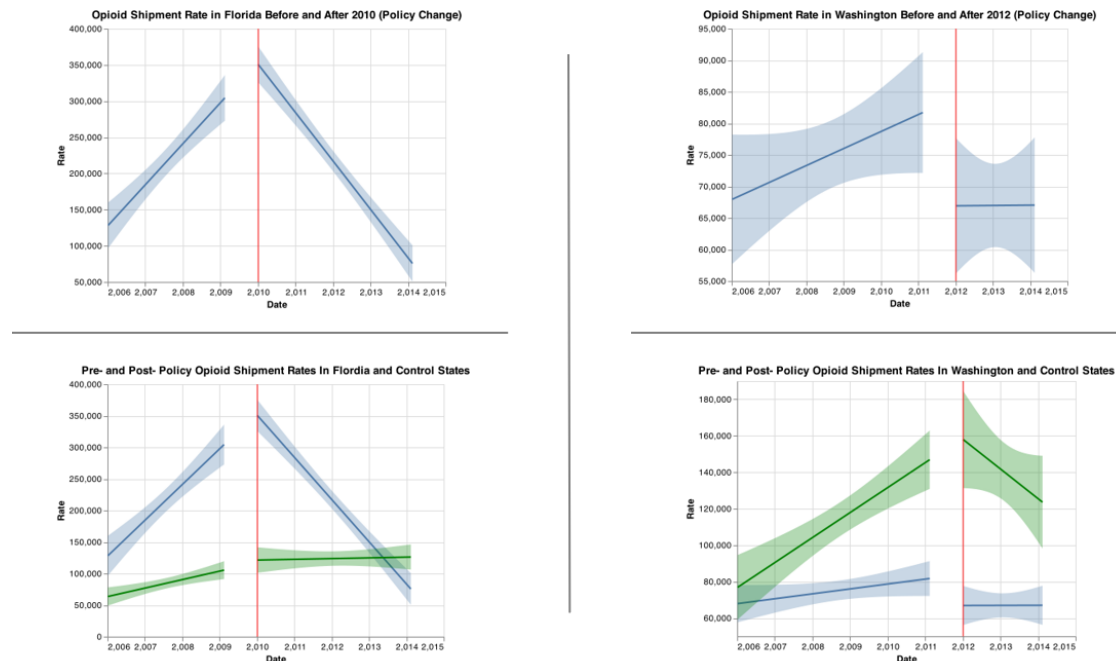

Figure 3: Opioid shipment data for Florida and Washington in top row. Target and comparison states in the bottom row. Target states in BLUE, comparison states in GREEN.

Opioid shipments in Florida were increasing in the years before the policy change and started a steep, decreasing trend after the change. Shipments into Washington were not increasing quite as drastically as they were in Florida, nor did they achieve the decreasing trend Florida saw. Washington did drop its number of shipments coming in after 2012 but shows a somewhat constant trend until 2014.

Florida had a very steep incline in opioid shipment rates before it changed its policies, then saw a clear decline, while its comparison states continued to see increasing shipment rates, which indicates that the policy change in Florida was successful in curbing opioid shipments.

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lower to a higher tier in the DEA schedule[12]). With regard to Washington's comparison states, there was a national trend that reflected the levelling out in opioid prescriptions after two major papers raised awareness in the medical community in 2009 and 2010[13] [14], and there was a 13.1% decline in prescriptions nationally between 2012 and 2015[15], which may be what is reflected in the decline in shipments in Washington's comparison states.

Limitations

It is important to keep in mind that while analyzing the outcomes of policy changes on a state level is relevant, a useful addition would be to complete the same analyses on a national level in order to tease out more general versus local effects. There are many strategies that can be and have been adopted, including raising awareness in the medical community over opioid prescriptions, which may affect opioid shipments to pharmacies more than a policy change might; or there could be changes to drug enforcement policies or to opioid buyback programs[16].

In addition, this data is solely focused on the U.S. and several of its states, but it could be relevant to consider how illicit drug use might be fueled by changes in policies in our neighboring countries, like Canada, Mexico, Central America, and South America.

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[12] Fulton-Kehoe, Deborah PhD; Lofy, Kathryn H. MD; Le, Vi MS; Sterling, Ryan PhD; Sears, Jeanne M. PhD; Franklin, Gary MD Opioid-Prescribing Metrics in Washington State: Trends and Challenges, Journal of Public Health Management and Practice: May/June 2020 - Volume 26 - Issue 3 - p 214-221 doi: 10.1097/PHH.0000000000001149

[13] Chou et al., Clinical Guidelines for the Use of Chronic Opioid Therapy in Chronic Noncancer Pain, J Pain. 2009 February ; 10(2): 113–130. doi:10.1016/j.jpain.2008.10.008.

[14] The Management of Opioid Therapy for Chronic Pain Working Group, VA/DoD CLINICAL PRACTICE GUIDELINE FOR MANAGEMENT OF OPIOID THERAPY FOR CHRONIC PAIN, Department of Veterans Affairs Department of Defense, United States Army MEDCOM Final Draft 306-1

[15] Guy GP Jr., Zhang K, Bohm MK, et al. Vital Signs: Changes in Opioid Prescribing in the United States, 2006–2015. MMWR Morb Mortal Wkly Rep 2017;66:697–704. DOI: http://dx.doi.org/10.15585/mmwr.mm6626a4

[16] Soelberg CD, Brown RE Jr, Du Vivier D, Meyer JE, Ramachandran BK. The US Opioid Crisis: Current Federal and State Legal Issues. Anesth Analg. 2017 Nov;125(5):1675-1681. doi: 10.1213/ANE.0000000000002403. PMID: 29049113