**Report for Nick Eubank**

**Estimate the Impact of Opioid Control Policies**

Grey Team (Nick Carroll, Jiaxin Ying, Emmanuel Ruhamyankaka, Song Young Oh)

**Motivation**

For more than 30 years, the United States has suffered a widespread crisis of opioid addiction and overdose deaths. As a result, there have been significant policy efforts to address the opioid crisis. Led by the White House's Office of National Drug Control Policy [1], federal agencies such as the Drug Enforcement Agency (DEA), the Centers for Disease Control and Prevention (CDC), the Department of Health and Social Services (DHSS), and the National Institutes of Health (NIH) have taken several initiatives to combat it [2].

In addition to these efforts at the federal level, there has been enforcement of state-level opioid control policies in various parts of the US. For instance, the Texas Medical Board adopted regulations with regards to treating pain with controlled substances in 2007. The Florida legislature also required pain clinics who treat pain with controlled substances to register with the state starting in 2010, and the Washington Department of Health adopted a rule regulating the prescription of opioids for pain treatment in 2012.

Understanding the impact of these state-level drug policies on public health allows policy makers to implement best practices and update policies that are ineffective. In particular, the intent of these regulations is to reduce opioid abuse; however, they have the possibility for unintended effects by limiting legal access of drugs to addicts.

This analysis aims to assess causal effects of opioid drug prescription regulations implemented in three states (Texas, Florida, Washington) in the early 2000’s (2007, 2010, and 2012 respectively). In particular, this analysis assessed the impact of the regulations on the volume of opioid shipments and drug overdose deaths.

**Motivation for Research Design**

The analysis will be implemented to answer the following two research questions.

1. For Florida and Washington: What is the effect of policy change on both opioid shipments and overdose deaths from 2003-2015?
2. For Texas: What is the effect of policy change on overdose opioid deaths from 2003-2015?

To draw valid inference on causal effects of these three policies, two kinds of approaches will be mainly used in the analysis. From an intuitive perspective, the first approach is pre-post comparison which focuses on difference between pre-policy and post-policy outcomes. Thus, this analysis will compare the amount of opioids prescribed and the amount of drug overdose deaths to their respective quantities, both before and after the policies took place in their respective jurisdictions. The second approach is a difference-in-difference method which compares the changes in outcomes over time between a state with a policy change and other states without the policy change. Each jurisdiction will be compared to the quantities in comparison states where no policies are in place.

**Details of the Data**

In the analysis, three datasets were used to examine the effectiveness of opioid control policies implemented in Texas, Florida, and Washington.

1. Opioid Drug Shipment Data: This dataset provided by The Washington Post details drug transactions reported to the Drug Enforcement Administration between pharmaceutical suppliers and pharmacies between 2006 to 2014. This dataset includes DEA reporter information for the supplier, pharmacy information, and sale information, including the drug, quantity, and sale date.
2. Vital Statistics Mortality Data: The US Underlying Cause of Death statistics includes quantities of deaths in each year, broken down by each county, and includes the cause of death as qualified by drug or alcohol induced.
3. US Census Population Data: The US Census population estimate dataset includes jurisdictional coding information, population estimates for each year, population change estimates (including births and deaths), along with a number of other estimates which aren’t relevant to this analysis.

**Methods**

To understand the impact that these policies had on opioid shipments and overdose deaths, a linear regression of average annualized opioid shipments per capita and overdose deaths per capita were calculated and plotted for each impacted jurisdiction. Two plots were made for each jurisdiction, for each variable analyzed: one which compared the linear trend prior to policy implementation against the linear trend after the policy implementation, and one which compared these linear trends against the linear trends for their control group.

To calculate the linear regressions for average annualized opioid shipments per capita, the opioid drug shipment data was filtered for the buyer’s county, the transaction date, and the quantity of drug along with its conversion factor (opioids are sold in pills, but they are reported in grams and not all pills have the same strength, so the conversion factor is used to compare relative strength/appropriate dose). Once the data was filtered, the units were converted to the appropriate “morphine milligram equivalent” units, and the quantities within a given county and year were totaled. Then, the census population estimates were used to calculate the total opioids shipped per capita to each county for each year. Next, the opioids shipped per capita were averaged over all the counties to provide a single average per capita estimate of opioids shipped per capita for the state for each year. Finally, the data was split into the periods prior to policy implementation and after policy implementation, and linear regression trend lines, along with confidence intervals, were calculated for each.

Similarly, to calculate the linear regressions for average annualized overdose deaths per capita, the mortality data was filtered for deaths that were considered drug induced, and the census data was used to calculate the drug induced deaths per capita for each county. Then, the drug induced deaths were averaged over all the counties for an average drug induced death rate per capita for each year. And finally, the data was split into the periods prior to policy implementation and after policy implementation, and linear regression trend lines, along with confidence intervals, were calculated for each.

**Comparison States**

For this causal inference analysis, the trends of each jurisdiction which implemented a policy was compared against the averages of three states for their own control group. Each control group’s three states were selected based on their similarity to the treated state. The metrics used to define “similarity” were population size and opioid dispensing rate. For this decision, population size was provided by World Population Review [3], and the opioid dispensing rate was provided by Centers for Disease Control and Prevention [4]. As shown in Table 1, the states which have the most “similarity” with each treated state in question was sorted with a sum of the difference in these two metrics. Based on this result, Florida’s comparison states will be Michigan, North Carolina, and Ohio. Texas will have Pennsylvania, Virginia, and Massachusetts as its control states, and Washington will be compared with Missouri, Georgia, and Arizona throughout the analysis.

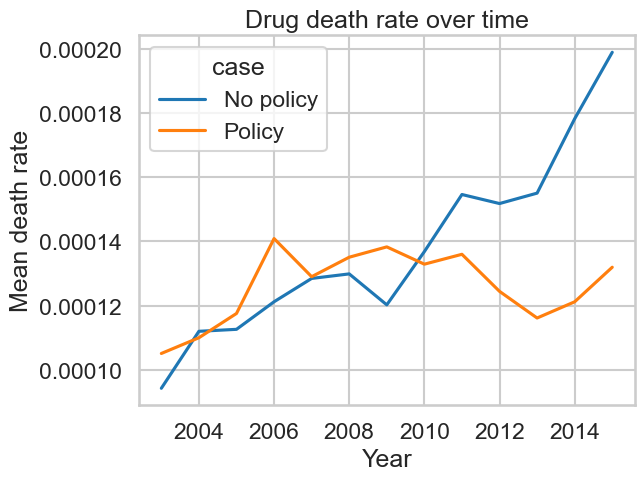
*Table 1: Selection of Comparison States by Comparing Population Size and Opioid Dispensing Rate*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treated State** | **Control**  **States** | **2022**  **Population**  **Ranking** | **2006**  **Dispensing**  **Rate** | **Population**  **Ranking Diff.**  **(A)** | **Dispensing**  **Rate Diff.**  **(B)** | **Total Diff.**  **(A+B)** |
| Florida | Michigan | 10 | 80.2 | 7 | 0.5 | 7.5 |
| North Carolina | 9 | 85.2 | 6 | 5.5 | 11.5 |
| Ohio | 7 | 87.7 | 4 | 8.0 | 12.0 |
| Pennsylvania | 5 | 69.5 | 2 | 10.2 | 12.2 |
| Missouri | 18 | 80.5 | 15 | 0.8 | 15.8 |
| Texas | Pennsylvania | 5 | 69.5 | 3 | 2.7 | 5.7 |
| Virginia | 12 | 67.2 | 10 | 0.4 | 10.4 |
| Massachusetts | 15 | 66.0 | 13 | 0.8 | 13.8 |
| Illinois | 6 | 55.6 | 4 | 11.2 | 15.2 |
| Arizona | 14 | 74.3 | 12 | 7.5 | 19.5 |
| Washington | Missouri | 18 | 80.5 | 5 | 0.3 | 5.3 |
| Georgia | 8 | 79.8 | 5 | 1.0 | 6.0 |
| Arizona | 14 | 74.3 | 1 | 6.5 | 7.5 |
| North Carolina | 9 | 85.2 | 4 | 4.4 | 8.4 |
| Ohio | 7 | 87.7 | 6 | 6.9 | 12.9 |

**Summary statistics**

**Mortality Rate of Opioid Overdose**

The mortality dataset includes 362 counties. The average number of fatalities among the counties is 52.695, with a standard deviation of 78.9. At the county level, Ellis County in Texas and 25 other states have the lowest mean number of deaths which is 10, while Maricopa County has the highest mean number of deaths of 571. At the state level, the maximum number of deaths is 748 and 10 is the lowest number of deaths across the years. Normalized to the population level, Dickenson County in VA has the highest death rate of 0.065% and Hidalgo County in Texas has the lowest death rate of 0.0023%. The graph below compares the general trend in death rates between the control states with no policy and the policy-implemented states. Overall, we may observe a substantial rise in deathrates for states without policies compared to states with policies.



*Figure A: Shows a general trend of deathrates between intervention and control states*

**Rate of Opioid Shipment**

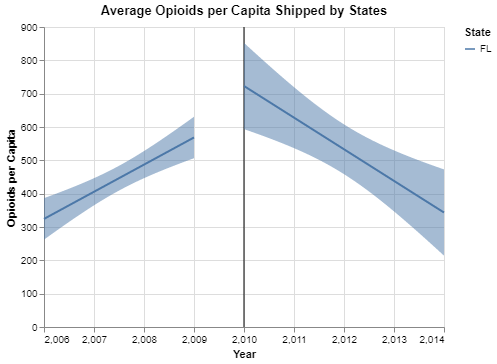
**Analysis**

The hypothesis is that the trend in average annual per capita opioid shipments, and overdose deaths is lower in the states where regulations were implemented when compared against the same jurisdiction prior to implementation, and against jurisdictions where no new policies were implemented. To analyze the validity of the hypothesis, it is expected that the trend for each of these quantities should be substantially less after the policies were implemented than before, and that the trend should be substantially less for the treated states when compared to the control groups. Otherwise, the hypothesis will be rejected if either quantity’s trend continues at a similar rate, or at a rate similar to the control group.

**Effect of regulation policy on opioid shipments**

**Florida**

Below is the plot comparing the trend of the average annual per capita opioid shipments before and after policy implementation in Florida. Before the policy went into effect in January 2010, the trend of average per capita opioid shipments in Florida was positive, increasing at a rate of approximately 100 per year. After 2010, the trend turned negative, decreasing at a rate of approximately 100 per year. This substantial change in trend supports the hypothesis that the policy reduced the amount of opioids shipped to Florida.



*Fig 1: Opioids per capita for the intervention state Florida*

The following plot below is the plot comparing the trend of the average annual per capita opioid shipments for Florida against Florida’s control states, both before and after policy implementation. When comparing these two trends, Florida’s trend after the policy was implemented was both substantially less than their control states’ and had a much larger reduction in trend than their control states when compared to prior to the policy implementation. This substantial reduction in trend when compared to the control states also supports the hypothesis that the policy reduced the quantity of opioids shipped to Florida. Therefore, with respect to reduction of opioids distributed to Florida, this suggests that Florida’s policy has been effective.

*Chart, line chart

Description automatically generated*

*Fig2. Average opioids per capita for Florida and its control states*

**Washington**

Below is the plot comparing the trend of the average annual per capita opioid shipments before and after policy implementation in Washington. Before the policy went into effect in January 2012, the trend of average per capita opioid shipments in Washington was positive, increasing at a rate of approximately 20 per year. After 2012, the trend appears flat. While the trend has reduced when comparing the period prior to policy implementation and after policy implementation, this reduction appears moderate, and not substantial. This small reduction in trend warrants further analysis prior to supports the hypothesis that the policy reduced the amount of opioids shipped to Washington.

**Chart, line chart

Description automatically generated**

The following plot below is the plot comparing the trend of the average annual per capita opioid shipments for Washington against Washington’s control states, both before and after policy implementation. When comparing these two trends, Washington’s trend after the policy was implemented was both substantially less negative than their control states’ and had a much smaller reduction in trend than their control states when comparing against prior to the policy implementation. This limited reduction in trend when compared to the control states does not support the hypothesis that the policy reduced the quantity of opioids shipped to Washington. Therefore, with respect to reduction of opioids distributed to Washington, this suggests that Washington’s policy has been ineffective.

**Chart, line chart

Description automatically generated**

**Effect of regulation policy on the mortality rate of opioid overdose**

**Florida**

Below are the plots comparing the trends of the average annual per 100000 drug-induced deaths in Florida and its control states, before and after policy implementation in Florida. Before the policy went into effect in February 2010, the trend of average per 100000 drug-induced deaths in Florida was positive, increasing at a rate of approximately 0.75 per year. After 2010, the trend turned negative, decreasing at a rate of approximately 0.5 per year. This substantial change in trend supports the hypothesis that the policy reduced the quantity of drug-induced deaths in Florida. When comparing Florida’s trend against its control group, Florida’s trend after the policy was implemented was both substantially less than their control states’ and had a reduction in trend when compared to an increase in trend in their control states’, when compared to prior to the policy implementation.

**Chart, line chart

Description automatically generated**

**Chart

Description automatically generated**

*Figure 1: Chart of the mortality rate of opioid-drug overdose between the pre-policy and post-policy periods, the regulation policy was effective in Florida in February 2010.*

After Florida implement the regulation policy for opioid drugs in 2010, it is obvious that the mortality rate of opioid-drug overdose has a decreasing tendency based on the left graph. Also, the right graph indicates the comparison between FL and its control states (MI, OH, NC) without implementing policies. It is evident that the mortality rate of opioid-drug overdose in these control states continues to hold an increasing trend after 2010. Based on the left graph, without implementing the regulation policy for opioid drugs, the average mortality rate per 100000 of opioid-drug overdose had a rising trend from 12 year by year since 2003 and peaked at about 16.75 in 2009. After Florida implemented the regulation policy for opioid drugs in 2010, the mortality rate per 100000 of opioid-drug overdose in FL dropped immediately to about 15.75 in 2010 and it continued to keep a downward tendency from 2010. This might not happen if the regulation policy was not implemented. Moreover, according to difference-in-difference analysis, the average mortality rate per 100000 of opioid-drug overdose for the three comparison states was about two lower than the average mortality rate of Florida from 2003 to 2009 while all of them held increasing tendencies of the mortality rate of opioid-drug overdose. However, the three comparison states still had an upward trend of mortality rate after 2010, this tendency is the same as before 2010. Furthermore, it is evident that the variations of drug overdose deaths between pre and post policy periods among Florida and its control states became greater since 2010. In 2015, the average mortality rate per 100000 of opioid-drug overdose for the three comparison states was about 7.5 higher than the average mortality rate of Florida. In general, the mortality rate per 100000 in control states increased from about 15 in 2010 to about 21.5 in 2015, while the mortality rate per 100000 of opioid-drug overdose in Florida decreased from 2010 at about 16 to about 14 in 2015. Therefore, we conclude that the policy of opioid regulations had a positive impact on decreasing the mortality rate of opioid-drug overdose in Florida.

**Texas**

Below are the plots comparing the trends of the average annual per 100000 drug-induced deaths in Texas and its control states, before and after policy implementation in Texas. Before the policy went into effect in January 2007, the trend of average per 100000 drug-induced deaths in Texas was positive, increasing at a rate of approximately 1.25 per year. After 2007, the trend turned negative, decreasing at a rate of approximately 1.3 per year. This substantial change in trend supports the hypothesis that the policy reduced the quantity of drug-induced deaths in Texas. When comparing Texas’s trend against its control group, Texas’s trend after the policy was implemented was both substantially less than their control states’ and had a reduction in trend when compared to an increase in trend in their control states’, when compared to prior to the policy implementation.

**Chart

Description automatically generatedChart, line chart

Description automatically generated**

*Figure 2: Chart of the mortality rate of opioid-drug overdose between the pre-policy and post-policy periods, the regulation policy was effective in Texas in January 2007.*

After Texas implement the regulation policy for opioid drugs in 2007, it is obvious that the mortality rate of opioid-drug overdose has a relatively decreasing tendency based on the left graph. Also, the right graph indicates the comparison between TX and its control states (MA, PA, VA) without implementing policies. It is obvious that the mortality rate of opioid-drug overdose in these control states continues to hold an increasing trend after 2007. Based on the left graph, without implementing the regulation policy for opioid drugs, the average mortality rate per 100000 of opioid-drug overdose had an increasing trend from about 8 year by year since 2003 and peaked at about 12 in 2006. After implementing the regulation policy for opioid drugs in 2007 at TX, the mortality rate per 100000 of opioid-drug overdose in TX dropped immediately to about 0.0105% in 2007 and it continued to keep a downward tendency from 2007. This might not happen if the regulation policy was not implemented. Moreover, according to difference-in-difference analysis, the average mortality rate per 100000 for the three comparison states are 3 higher than the average mortality rate per 100000 in Texas from 2003 to 2006 while all of them held increasing tendencies of the mortality rate per 100000 of opioid-drug overdose. Nevertheless, the three comparison states still had an upward trend of mortality rate after 2007, this tendency is the same as before 2007. Moreover, it is obvious that the variations of drug overdose deaths between pre and post policy periods among Texas and its control states became greater since 2007. In 2015, the average mortality rate per 100000 of opioid-drug overdose for the three comparison states was about 9 higher than the average mortality rate of Texas. In general, the mortality rate per 100000 in control states increased from about 13 in 2007 to about 19 in 2015, while the mortality rate per 100000 of opioid-drug overdose in Texas decreased from 2007 about 11 to about 10 in 20. Hence, although such a degree of decline is not large, we conclude that the policy of opioid regulations had a positive impact on decreasing the mortality rate of opioid-drug overdose in Texas.

**Washington**

Below are the plots comparing the trends of the average annual per 100000 drug-induced deaths in Washington and its control states, before and after policy implementation in Washington. Before the policy went into effect in January 2012, the trend of average per 100000 drug-induced deaths in Washington was positive, increasing at a rate of approximately 0.25 per year. After 2012, the trend was still positive but with a lower slope, increasing at a rate of approximately 0.07 per year. Consequently, this change in trend does not support the hypothesis that the policy reduced the quantity of drug-induced deaths in Washington.

Chart, line chart

Description automatically generatedChart, line chart

Description automatically generated

*Figure 3: Chart of the mortality rate of opioid-drug overdose between the pre-policy and post-policy periods, the regulation policy was effective in Washington in January 2012.*

After Washington implement the regulation policy for opioid drugs in 2012, the mortality rate per 100000 of opioid-drug overdose still had a decreasing, but lesser degree tendency based on the left graph. Also, the right graph indicates the comparison between WA and its control states (MO, GA, AZ) without implementing policies. It is obvious that the mortality rate per 100000 of opioid-drug overdose in these control states continues to hold an increasing trend after 2007. Based on the left graph, without implementing the regulation policy for opioid drugs, the average mortality rate per 100000 of opioid-drug overdose had an increasing trend from about 12.25 year by year since 2003 and peaked at about 14.25 in 2011. However, after implementing the regulation policy for opioid drugs in 2012 at WA, the mortality rate of opioid-drug overdose in WA did not drop, it continued to keep an upward, but lesser degree tendency from 2012. Furthermore, according to difference-in-difference analysis, the slope of average mortality rate for the three comparison states was larger than the slope of average mortality rate of Washington from 2003 to 2011 while all of them held increasing tendencies of the mortality rate per 100000 of opioid-drug overdose. The three comparison states still had an upward trend of mortality rate after 2012, this tendency is the same as before 2012. In general, the mortality rate in control states increased from about 15.5 in 2012 to about 16.5 in 2015, and the mortality rate per 100000 of opioid-drug overdose in Washington also rose from 2012 at about 13.8 to about 14 in 2015. Therefore, although the mortality rates per 100000 of opioid-drug overdose in Washington were lower than other control states on average after implementing the policy; because Washington still had a rising trend of mortality rates of opioid-drug overdose after 2012, we conclude that the policy of opioid regulations did not have a positive impact on decreasing the mortality rate of opioid-drug overdose in Washington.

**Interpretation of the Analysis**

Based on this analysis, Florida and Texas were able to implement policies that reduced drug-induced deaths, and Florida’s policy was able to limit the amount of opioids shipped to the state. With appropriate data, similar analysis would be able to confirm if Texas was able to limit opioids shipped to the state. Conversely, based on this analysis, the policy that Washington implemented in 2012 was unable to substantially reduce the quantity of opioids shipped to the state, or the drug-induced deaths in the state.

**Limitations**

Despite key takeaways from this analysis, extracting causal information from drug policy analysis is still challenging. Many states have enacted multiple opioid control policies as the opioid crisis has evolved over the decades. For example, several states implemented a combination of naloxone laws, Good Samaritan laws, and medical marijuana laws during 2015-2017. Furthermore, in addition to pre-existing prescription drug monitoring program (PDMP) laws, by 2017 most states had implemented at least 3 of these 4 categories of policies [5]. Therefore, it is difficult to ascertain appropriate control groups and ensure all confounding variables are accounted for. These factors complicate valid inference on causal effects of opioid control policies.

**Conclusion**

Based on this analysis, Florida and Texas have been able to implement successful policies to combat the opioid epidemic and should be used as a best practice case study for other states who continue to struggle in reducing opioid deaths and over-prescription of opioids. Conversely, Washington’s policy in 2012 has been shown to be relatively ineffective at combating the opioid epidemic and should be updated to follow more closely Florida’s implementation, which has been substantially more successful.

**References**

[1] "National drug control budget (2021)." [Online]. Available: https://www.whitehouse.gov/wp-content/uploads/2021/05/National-Drug-Control-Budget-FY-2022-Funding-Highlights.pdf

[2] C.D. Soelberg, R.E. Brown, D.Du Vivier, J.E. Meyer, and B.K. Ramachandran, "The us opioid crisis - current federal and state legal issues," Anesthesia and Analgesia, vol.125, no.5, p.1675-1681, 2017.

[3] Available: <https://worldpopulationreview.com/states>

[4] Available: <https://www.cdc.gov/drugoverdose/rxrate-maps/state2020.html>

[5] Griffin, B.A., Schuler, M.S., Pane, J. et al. Methodological considerations for estimating policy effects in the context of co-occurring policies. Health Serv Outcomes Res Method (2022).