**Report for Nick Eubank**

**Estimate the Impact of Opioid Control Policies**

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**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 began to require that pain clinics treating pain with controlled substances register with the state since 2010, and the Washington Department of Health adopted a rule regulating the prescribing of opioids for pain treatment in 2012.

Evaluating the impact of these state-level drug policies on public health outcomes matters in policy research. It is because their geographic and temporal variation in policy adoption can offer an insight into better understanding about the drug policy effects. Moreover, while the intent of these regulations is meant to reduce opioid abuse, they can increase the ability of addicts to access opioids legally and may have unexpected effects.

Therefore, this analysis aims to assess causal effects of opioid drug prescription regulations enforced in three states (Texas, Florida, Washington) in the early 2000’s (2007, 2010, and 2012 respectively), on the US society, and in particular on the volume of opioids shipment 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 will be used to examine the effectiveness of opioid control policies implemented in Texas, Florida, and Washington.

1. Opioid Drug Shipment Data: The Washington Post dataset offers county-level information about drug transactions from 2006 to 2014 that are sourced by the Drug Enforcement Administration's database which tracks quantities of drugs sold from pharmaceutical suppliers to pharmacies. This dataset contains information for the supplier, pharmacy information, and sales information, including the drug, quantity, and transaction date.
2. Vital Statistics Mortality Data: The US Vital Statistics dataset contains data on every drug overdose death in the US from 2003 to 2015. This dataset 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 dataset has population estimates for each county in the US from 2000 to 2020. The dataset contains jurisdictional FIPS code information, population estimates for each year, population change estimates (including births and deaths), along with a number of other estimates.

**Methods**

For the analysis, the annual percent change of per capita opioid quantities sold and annual percent change in overdose deaths will be calculated for each year in the 2003-2015 period, and for each jurisdiction (Florida, Washington, Texas, and their comparison states where no policy was implemented). To calculate the final variables, a set of necessary data will be selected from the datasets and aggregated annually. Specifically, the values which will be collected from the Washington Post dataset are buyer state, buyer county, quantity of drug purchased, drug, transaction data, quantity weight, and dosage. This data will be filtered for drugs that are considered opioids and aggregated over the county and year to calculate the total annual amount of opioids purchased from pharmaceutical suppliers in each county. Similarly, the values selected from the US Vital Statistics dataset are county, year, cause of death, and number of deaths. This data will be filtered for cause of deaths that are considered opioid overdoses and aggregated over the county and year to calculate the total number of opioid overdose deaths annually in each county. Finally, the values selected from the US Census dataset are county and population estimate for each year over the time period analyzed. With the aggregated data from the other two datasets, county and population estimate data will be used to calculate annual per capita opioids purchased in each jurisdiction and annual per capita opioid overdoses in each jurisdiction. The FIPS codes will especially serve as a key variable in merging datasets by the unit of county.

**Comparison States**

As a control group of this causal inference research, three states have been chosen for each state with an opioid regulation policy change. Since the main assumption behind causal inference is randomization which makes treatment and control groups comparable before the policy action takes place, the three comparison states need to be selected based on their similarity to the treated state. For a benchmark of the similarity, both population size and opioid dispensing rate are taken into consideration in the analysis. The source of the population size is the recent projection about this year’s population provided by World Population Review [3], and the source of the opioid dispensing rate is each state’s opioid dispensing rate per 100 persons in the year of 2020 provided by Centers for Disease Control and Prevention [4]. As shown in Table 1, three states which have the least difference with each treated state are sorted given the two criteria. Based on this result, Florida’s comparison states will be Pennsylvania, Ohio, and Georgia. Texas will have Illinois, New York, and Virginia as its control states, and Washington will be compared with Arizona, Maryland, and Wisconsin throughout the analysis.

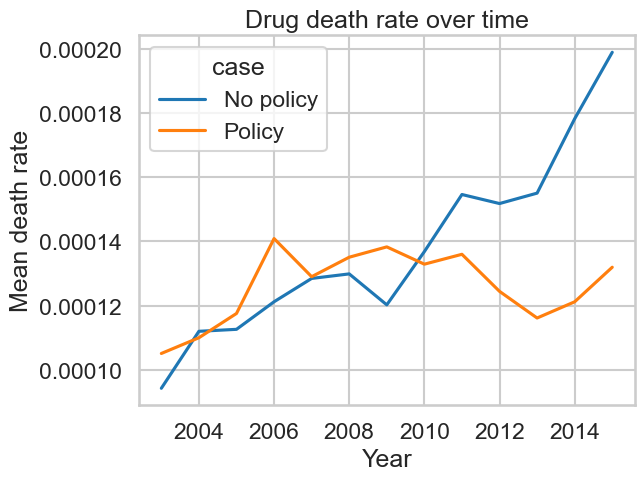
*Table 1: Selection of Comparison States by Comparing Population Size and Opioid Dispensing Rate*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treated State** | **Control**  **States** | **2022**  **Population**  **Ranking** | **2020**  **Dispensing**  **Rate** | **Population**  **Ranking Diff.**  **(A)** | **Dispensing**  **Rate Diff.**  **(B)** | **Total Score**  **(A+B)** |
| Florida | Pennsylvania | 5 | 43.1 | 2 | 0.3 | 2.3 |
| Ohio | 7 | 47.4 | 4 | 4.0 | 8.0 |
| Georgia | 8 | 53.9 | 5 | 10.5 | 15.5 |
| California | 1 | 28.5 | 2 | 14.9 | 16.9 |
| Michigan | 10 | 54.4 | 7 | 11.0 | 18.0 |
| Texas | Illinois | 6 | 40.2 | 4 | 2.3 | 6.3 |
| New York | 4 | 31.9 | 2 | 6.0 | 8.0 |
| Virginia | 12 | 37.6 | 10 | 0.3 | 10.3 |
| California | 1 | 28.5 | 1 | 9.4 | 10.4 |
| Ohio | 7 | 47.4 | 5 | 9.5 | 14.5 |
| Washington | Arizona | 14 | 40.5 | 1 | 1.0 | 2.0 |
| Maryland | 19 | 39.5 | 6 | 0.0 | 6.0 |
| Wisconsin | 20 | 39.6 | 7 | 0.1 | 7.1 |
| Illinois | 6 | 40.2 | 7 | 0.7 | 7.7 |
| Massachusetts | 15 | 33.3 | 2 | 6.2 | 8.3 |

Summary statistics - Mortality

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.

*Fig 1: Shows a general trend of deathrates between intervention and control states*



**Pre-post and Difference-in-difference Analysis**

The hypothesis is that the average annual percent change in per capita opioid quantities sold, 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 hypothesis is reasonable if the average annual percent change in per capita opioid quantities sold, and opioid-drug-overdose deaths should be substantially less after the policies were placed than before the polices were introduced for each jurisdiction. Otherwise, the hypothesis will be rejected if the opioid-drug-overdose deaths per capita or the opioid quantities sold per capita continue to increase or basically keep constant after the regulation policy change.

**Effect of regulation policy on opioid shipments - Florida**

In order to compare how things were in Florida right before the policy went into effect, to

Florida right after the policy went into effect, we conducted the pre-post analysis. The regression line in the graph above shows the trend of shipment quantity per cap before and after the policy change in the Florida, as is shown in the figure below.

*Fig 2: Opioids per capita for the intervention state Florida*

**Chart, line chart

Description automatically generated**

Before the policy went into effect in January 2010, the slope of the regression line was positive, indicating that the quantity of opioid shipment. After 2010, the slope was negative, indicating that the quantity of opioid shipment per cap decreased. It appears that Florida’s shipments are in accordance with the expectations of an accurate hypothesis and suggests that the opioid shipments were reduced from the policy; and therefore, the policy was effective. To reach a more reliable conclusion, additional analysis was necessary. We then carried out a difference-in-difference analysis in order to get a more concrete conclusion. By using the Difference-in-Difference approach, we are basically seeking to answer whether the change we saw in intervention state Florida is larger than the change that occurred in other states over the same period. In graphs below, we plot the pre and post trends of policy change for Florida state and its control group Georgia, Ohio and Pennsylvania.

*Fig3. Average opioids per capita for Florida and its control states*

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From fig3, we can see that before the policy change in 2010, Florida had similar upward trend with control group, and it’s at a higher level. After the policy changed, while control group barely changed its trend, Florida has experienced a significant change in trend, from upward sloping to downward slope. Hence, we can conclude that the level and trend of Florida Opioid shipments have changed after the policy took effect.

**Washington**

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It appears that Washington’s shipments do not meet the expectations of an accurate hypothesis and suggests that the opioid shipments were not reduced from the policy; and therefore, the policy was ineffective.

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

**Florida Chart, line chart

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*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 2020, 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 (PA, OH, GA) 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 of opioid-drug overdose had a rising trend from 0.012% year by year since 2003 and peaked at about 0.017% in 2009. After Florida implemented the regulation policy for opioid drugs in 2010, the mortality rate of opioid-drug overdose in FL dropped immediately to about 0.016% 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 of opioid-drug overdose for the three comparison states was 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. In general, the mortality rate in control states increased from about 0.015% in 2010 to about 0.022% in 2015, while the mortality rate of opioid-drug overdose in Florida decreased from 2010 at about 0.016% to about 0.014% 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**

Chart, line chart, surface chart

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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 (IL, NY, 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 of opioid-drug overdose had an increasing trend from about 0.008% year by year since 2003 and peaked at about 0.012% in 2006. After implementing the regulation policy for opioid drugs in 2007 at TX, the mortality rate 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 for the three comparison states had similar values as the average mortality rate of Texas from 2003 to 2006 while all of them held increasing tendencies of the mortality rate 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. In general, the mortality rate in control states increased from about 0.011% in 2007 to about 0.015% in 2015, while the mortality rate of opioid-drug overdose in Texas decreased from 2007 at about 0.011% to about 0.010% in 2015. Therefore, 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**

**Chart

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*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 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 (AZ, MD, WI) 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 of opioid-drug overdose had an increasing trend from about 0.0125% year by year since 2003 and peaked at about 0.0145% 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 average mortality rate for the three comparison states were lower than the average mortality rate of Washington from 2003 to 2011 while all of them held increasing tendencies of the mortality rate 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 2007. In general, the mortality rate in control states increased from about 0.015% in 2012 to about 0.017% in 2015, and the mortality rate of opioid-drug overdose in Washington also rose from 2012 at about 0.0138% to about 0.014% in 2015. Therefore, although the mortality rates 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 (to be added)**

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**Limitations**

Despite key takeaways from this analysis, extracting causal information from drug policy analysis is still challenging due to some reasons. Many states have generally enacted multiple opioid control policies as the opioid crisis has evolved for decades. For example, many states implemented some combination of naloxone laws, Good Samaritan laws, and medical marijuana laws during 2015-2017. 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 will be unreasonable to put too much emphasis on specific timepoints, namely the year of 2007 (Texas), 2010 (Florida), 2011 (Washington). Besides, it is almost impossible to identify perfect comparison states which were not impacted by the policy of interest at all. These factors serve to complicate valid inference on causal effects of opioid control policies.

**Conclusion (to be added)**

In this work, our approach of using pre-post comparison and difference-in-difference analysis has been presented to understand the effects of three opioid control policies executed in Florida, Texas, and Washington from a perspective of causal inference.

**References**

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