A Difference-in-Difference Study of the Effect of Gun Legislation between North Carolina and South Carolina, 1991-2016

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"Regulation of firearms in the United States of America is a highly publicised and debated issue. As the regulations are predominantly decided at state level, Ronan Dunne investigates the impact of introducing 'stand your ground laws' in South Carolina. 'Stand your ground laws' give individuals the right to use deadly force if they believe themselves to be in danger; it essentially removes the requirement to retreat if possible. Given similar trends in firearm deaths in North Carolina and South Carolina before the introduction of this law, Dunne conducts a difference-in-difference study, concluding that liberal firearm laws are associated with an increase in fireman related deaths."

Introduction

The United States of America is colloquially dubbed the 'gun capital of the world', owing to its extensive gun ownership rate coupled with its liberal firearm legislation encapsulated by the 2nd Amendment, "the right of the people to keep and bear Arms, shall not be infringed" (U.S. const. Amend. II). Civilian firearm ownership is relatively common in the US; at an estimated rate of 120.5 firearms per 100 civilians, placing it highest in the list of 230 countries surveyed in the Small Arms Survey, 2017 (Karp, 2018). Recently, firearm related deaths have become a prevalent and controversial public health debate; accounting for approximately 30,000 deaths in the US in 2017 - a rate of 10 deaths per 100,000 (Centre for Disease and Control and Prevention, 2018).

The regulation of firearms is primarily the responsibility of the State, so long as lislation remains within the bounds of Federal Law. This provides ideal grounds for a difference-in-difference (DD) approach as regulations are applied heterogeneously between States, but homogeneously within States. This paper aims to assess whether more liberal firearm laws, via 'stand your ground laws', have an impact on firearm related deaths in North Carolina (NC) and South Carolina (SC). The proposed treatment effect is the introduction of 'stand your ground laws' in SC on 9 June 2006, which are defined as, "[a] person who is not engaged in an unlawful activity and who is attacked in another place where he has a right to be, including, but not limited to, his place of business, has no duty to retreat and has the right to stand his ground and meet force with force, including deadly force" (S.C. Code Section 16-11-440(C)). NC has no such law, meaning citizens do not have the right to stand their ground in face of danger.

In this paper, trends and levels of firearm related deaths were examined in NC and SC in the years 1991 to 2016. Given that many studies of legislative intervention suffer from confounding variables (Skelly et al. 2012), the impact of legislation introduced in SC was examined using a DD method. This approach mitigates the effects of confounders. Studies of this nature are seldom, and this one is the first to test inter-State gun laws. If proven, this could have major policy implications. Further, it is hypothesized that legislation that allows individuals to stand their ground will induce an increase in firearm related deaths in SC.

Literature Review

Despite gun prevalence in the US commune, research is limited - mostly due to gun lobbying on behalf of the National Rifle Association (NRA), "the NRA officially spends about $3m per year to influence gun policy" and "considerable sums are spent elsewhere via PACs and independent expenditures - funds which are difficult to track" (BBC, 2020). In 1996 the US Congress introduced Dickey Amendment (Rostron, 2018), that redirected funds intended to research gun control. However, in their 2001 paper, Webster et al. found that states with registration and licensing systems are more effective in reducing firearm related deaths when compared to States that have either registration or licensing systems or neither registration or licensing systems. This was done vis-a-vis comparing gun state law categories with guns sold within states after legislation had been enacted 25 cities across the US. Luca et al (2017), adopted a DD to assess the causal impact of waiting periods on gun related deaths. The authors found that 17 states with waiting periods avoid approx. 750 deaths per annum when compared to states with no waiting period in the period 1970-2014. Further, by employing a DD study of the effectiveness of the expansion of the Gun Control Act (GCA) on the federal level, Raissian (2016) finds that limiting access to people with mental health disorders and individuals with previous convictions does reduce homicide vis-a-vis firearms. Both of these studies indicate the more liberal firearm laws are, the more deaths are seen. Moreover, there is no evidence of 'spill over' effects. Moving outside of the US, Langmann (2020) employs a DD with multiple treatments in Canada to assess the impact of legislation introduced between 1981 and 2016 on homicide and suicide by firearm in Canada.

Empirical Approach

The model used in this paper is a DD. One dependent variable is investigated, the crude death rate per 100,000 people. The unit of account are the counties in each State. The independent variables are the post variable, the treatment variable, the DD variable and the population variable. The post variable is a dummy variable which equals 1 if the death rate is between 2006 and 2016 and 0 if between 1991 and 2005. This measures the trend of firearm deaths overtime and is expected to be positive. The treatment variable is a dummy variable which equals 0 if the county is in NC, and equals 1 if the county is in SC. This measures the relative firearm deaths of NC to SC. It is expected to be positive given; NC higher population and larger gun industry. A DD technique was used to construct a quasi-experimental time series analysis to compare SC to NC exposed to the effects of firearms legislation. This variable is expected to be positive, meaning once the legislation is introduced it increases firearm related deaths over the period examined in SC versus NC. The variable population is a control variable, and is added to account for the changes in population over the period examined. The regression model follows that;

$$Deat\hat{h}Rate = \alpha - \beta_1(Post) - \beta_2(Treat) + \beta_3(DD)$$

Secondly, tests are run to determine if the parallel trend assumption holds. Firstly, the relationship is presented graphically. Secondly, a placebo DD regression is run to test the hypothesis that, in 1999, with no treatment effect, there is a zero DD variable.

Description of the dataset

The data used for this research is sourced via the Centre for Disease Control and Prevention (CDC). The data set contains 1,480 observations across the period 1991 to 2016. This data was used as it was readily formatted on the CDC website. NC has 100 counties and SC has 46 counties. Some of the data was suppressed due to confidentiality, amounting to approx. 200 data points being unavailable.

The average death rate in NC decreased by 14.2% following the introduction of the legislation, in contrast SC saw an average decrease of 2.32. Further insight into this is provided in Figure 1. This shows the distribution of deaths in the two States before and after the legislation introduction. Pre-legislation deaths in NC are uniformly spread out. Post-legislation, they are positively skewed. Interestingly, post-legislation, SC sees more outliers at the extreme values. This is expected, and represents an increase in firearm deaths in SC.

The sample is large enough that real inferences can be drawn from the regression. The parallel trend assumption data is also sourced vis-a-vis the Figure 2. From which, after the legislation is introduced, we see a clear deviation in death trends between NC and SC. This data is on the State level, that is each year takes the crude death rate per 100,000 NC and SC. From Figure 2, we see the parallel trend assumption is upheld, with similar death trend levels similar up until the intervention in 2004. Both NC and SC firearm deaths were on a downward trajectory, had SC not implanted a 'stand your ground law' it is assumed they would have continued on this path.

Summary statistics are presented in Figure 1.2. This shows the minimum (min), maximum (max), median, mean, standard error of the mean, variance and standard deviation (s.d) for the years 1995, 2000, 2005 and 2010. This is to show the trend over the time period. Across the 4 years examined, both NC and SC mean is greater than the median, indicating that deaths are positively skewed. This highlights that the complexion of deaths did not change over the period examined, both pre and post-treatment. This confirms the results in Figure 1. The mean death rate in NC remains stable over the 4 years, decreasing by approx. 4.01% (1995-2010), while in SC there is a 26% increase from 1995 to 2010. The s.d of deaths in NC is greater than SC in every year but 2005 (where the difference is negligible), representing a more dispersed death rate. Taking 2000, NC s.d means 95.4% of the death rates lie in between ±33.06 s.d of the mean. Conversely, in SC 95.4% of deaths lie within ±23.04 s.d of the mean in 2000. Interestingly, NC has more extreme values with the max death rate reaching 101.00 in 2010 while the max death rate in SC was 63.00 in 2010. This leads to a wider range of deaths in NC compared to SC. The NC range for the years are 90, 85, 83 and 91 respectively. Meanwhile, the SC range for the corresponding years are 40, 38, 48, and 53. This cements the hypothesis that SC deaths are more clustered around the mean.

Empirical Results

The results of the three models used are shown in Figure 3, with robust standard errors shown in parentheses. (1) is the simple DD regression model with no control variables.

$$Death\hat{h}Rate = 17.595 - 2.452(Post) - 0.561(Treat) + 2.432(DD) \qquad (1)$$

The R^2 and the adjusted R^2 are both very low, 0.027 and 0.025 respectively, see Figure 4. The R^2 indicates that the independent variables account for 2.7% of the variation in the death rate. This indicates that the independent variables are not explaining much of the variation in death rates over time. However, we see that the post variable is negative, and statistically significant at the 1%. This indicates that firearm deaths were trending downwards overtime regardless of the treatment. The treatment variable is negative but statistically insignificant. Importantly, we observe a positive and statistically significant DD variable at the 1% level. This indicates that after the legislation was introduced there was a real increase in firearm related deaths in SC versus NC. Further, the F-statistic is significant at the 1% level, indicating the joint significance of the model. This indicates that the model holds predictive power in spite of the low R^2 and adjusted R^2. Figure 5 presents the difference-in-difference table in a 2x2 matrix, and shows a slight increase in firearm deaths in SC versus NC. This confirms the original hypothesis that 'stand your ground laws' increase firearm related deaths.

$$Deat\hat{h}Rate = 20.100 - 1.900(Post) - 0.403(Treat) + 2.368(DD) - 0.00002(Pop) \qquad (2)$$

The regression model is run again, as seen in (2), with the control variable population to account for population changes between the two periods examined. Here we see the R2 is 0.186, meaning that 18.6% of the variation in firearm deaths is being explained by this model. Further the adjusted R2 indicates the penalty for adding the new variable, equalling 0.184 in model (2). This indicates that adding population does increase the descriptive power of the model. Furthermore, the F-Statistic remains statistically significant at the 1% level, indicating the joint significance of the model. The post variable remains negative and statistically significant at the 1% level. Although, the DD decreases in value to 2.268, and is statistically significant at the 1% level. The variable population is negative and statistically significant at the 1% level. Model (2) appears to improve the robustness on model (1).

Model (3) is run to confirm the parallel trend assumption. It is a placebo DD, with the pre-treatment variable being 1998 and the post variable equalling 2000. We see all three independent variables are statistically insignificant, this confirms the parallel trend assumption indicated by Figure 2. Although the variables are non-zero their statistical insignificance signals that the parallel trend assumption is upheld.

Therefore, the results from model (1) and its extension, model (2), have policy implications given their robustness. The results are in line with Luca et al. (2017), but at odds with Langmann (2020). The results indicate that liberal firearm laws increase the firearm death rate. As seen, by introducing 'stand your ground laws' SC saw an increase in firearm deaths. Should a State want to reduce firearm deaths, stand your ground laws should be revoked.

Discussion of Possible Extensions

The above model could be extended. Firstly, more robust checks for the internal validity of the model could be discussed. The treatment and control group could be tested to see the response to some non-related variable (Rosenbaum, 1987); such a factor could be suicide rates over the same period. Also, a similar but unrelated control group could be implemented to account for a real change in NC deaths versus this new control group.

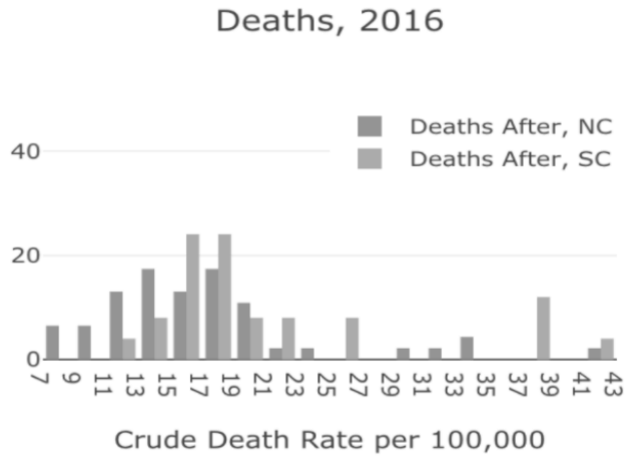
Moving away from sensitivity tests, more control variables could be added if they were available. GDP per capita of each County of each State could be added to account for changes in income over the period. Dummy variables to test for the effect on males, females and minority groups could also be added to assess if the legislation disproportionately impacts minority groups. This would have policy implications if shown to have a real impact. Further, the response to the treatment was not immediate, suggesting that there may be other factors influencing gun related deaths in NC and SC. This infers that a Generalised Method of Moments (GMM) model, as in Blundell and Bond (1998), could be used to have a lagging variable as the dependent variable, where the death rate lags. Indeed, this seems intuitive given the slow impact that policy implementation can have; especially given the strong cultural link between firearms and the US. Lastly, an extension of this study could be applied if SC repeals the 'stand your ground laws', as in Leary (2009), to assess the 'treatment reversal' effect; if the law is repealed do we see a reversal of the effect.

Conclusion

The results in model (1) show that liberal firearm laws increase firearm deaths. This is intuitive as if citizens are given the right to 'stand their ground' and use deadly force, they inadvertently will. A major caveat of this study is that the response to the legislation was not immediate. A GMM model was proposed to counter this but not explored. Indeed, with any natural or quasi-experimental experiment extrapolation of results is difficult. Internal validity is often inversely related to external validity. Nonetheless, this paper aimed to prove that more liberal firearm laws increase firearm deaths vis-a-vis a DD approach. Model (1) showed that SC experienced a statistically and economically meaningful increase in deaths after 2006. The robustness of model (1) motivated a new model, (2), which improved the descriptive power vis-a-vis the R^2 and adjusted R^2. A battery of robustness tests were explored, including the parallel trend assumption graph, the placebo DD along with robust standard errors. There are no 'spill over effects' to be concerned about as this paper did not test the restriction of firearm purchases in neighbouring States. Overall, this paper has proved what it set out to do, that more liberal firearm laws are associated with an increase in firearm related deaths.

Appendix

Figure 1.



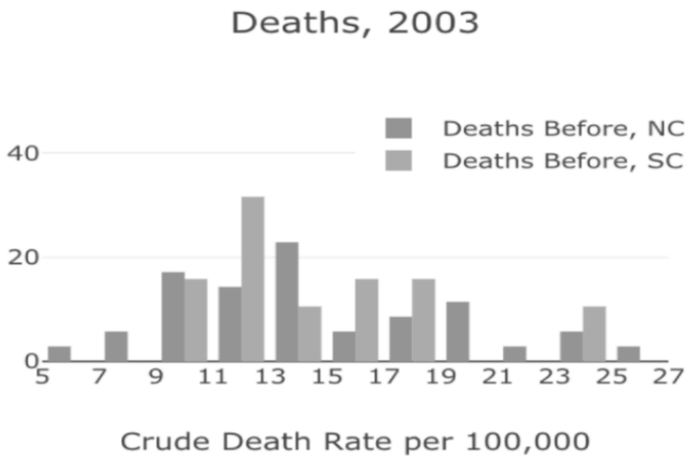
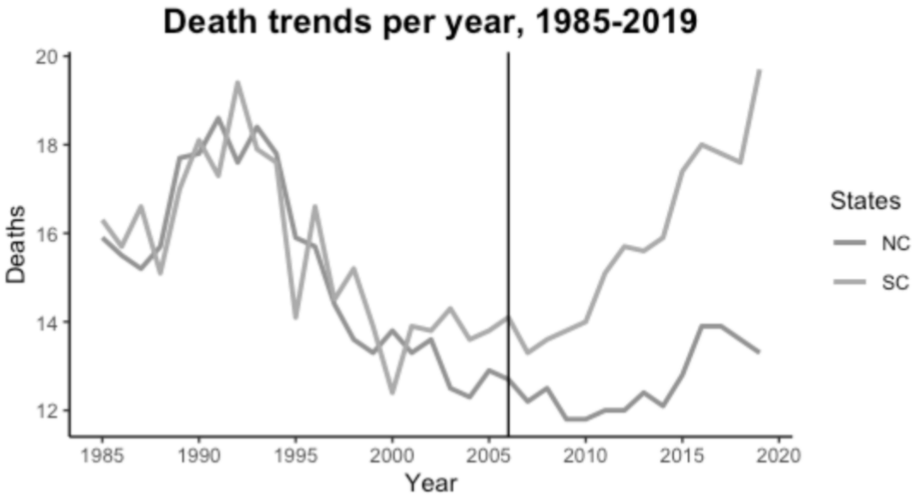


Figure 2



Firearm deaths, Figure 3

	Deaths: NC and SC		
	(1)	(2)	(3)
Post variable	-2.452***	-1.900***	0.317
	(0.397)	(0.363)	(1.362)
Treatment variable	-0.561	-0.403	1.351
	(0.519)	(0.478)	(1.935)
DiD	2.432***	2.268***	-1.903
	(0.707)	(0.646)	(2.760)
Population		-0.00002***	
		(0.00000)	
Constant	17.595***	20.100***	16.237***
	(0.306)	(0.340)	(1.076)
Significance levels	*p<0.1; **p<0.05; ***p<0.01		

Descriptive Statistics, Figure 1.2

North Carolina Deaths

	1995	2000	2005	2010
min	10.00	10.00	10.00	10.00
max	100.00	95.00	93.00	101.00
median	16.00	16.00	15.00	16.00
mean	22.19	22.15	21.05	21.30
SE.mean	2.68	2.65	2.37	2.48
var	302.60	273.34	235.27	263.55
std.dev	17.40	16.53	15.34	16.23

South Carolina Deaths

	1995	2000	2005	2010
min	10.00	10.00	10.00	10.00
max	50.00	48.00	58.00	63.00
median	15.50	19.50	21.00	21.00
mean	22.06	22.38	24.47	25.24
var	194.41	132.78	244.49	260.29
std.dev	13.94	11.52	15.64	16.13

Figure 4

	Deaths: NC and SC		
	(1)	(2)	(3)
Observations	1480	1480	
R2	0.027	0.186	
Adjusted R2	0.025	0.184	
F Statistic	14.03***	84.65***	
	(df=3, 1476)	(df=3, 1476)	

Significance levels *p<0.1; **p<0.05; ***p<0.01

Difference-in-Difference Table Model (1), Figure 5

	Pre	Post	Difference
South Carolina	17.034	17.014	-0.02
North Carolina	17.595	15.143	-2.452
Difference	-0.561	1.871	2.432

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