



# Rising Gun Sales in the Wake of Mass Shootings and Gun Legislation

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Accepted: 9 January 2021 / Published online: 2 February 2021

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## Abstract

Although gun control laws are intended to reduce exposure to gun violence in communities across the country, the passage of gun control laws is often linked to a substantial rise in the number of guns sold in the U.S. National polls indicate that most individuals purchase firearms for protection, but some cite the fear of gun-buying restrictions as the main reason for purchasing a gun. It is unclear what impact gun legislation has on patterns of gun sales, as mass shootings continue to bring the U.S. gun debate to the forefront. Using statewide data on gun transactions in Massachusetts from 2006 to 2016, we examined patterns in gun sales following the passage of gun legislation and high profile mass shootings. Specifically, we used three events to test and refine the argument during this time period: (1) the Newtown shooting, (2) the San Bernardino shooting, and (3) the passage of the 2014 Massachusetts Gun Violence Reduction Act. Results from these time-series analyses indicated different patterns in handgun sales, with significantly larger increases occurring among first-time handgun buyers. Our findings complement prior work explaining the impact of mass shootings and gun control laws on the exposure to guns in communities.

**Keywords** Guns · Gun policy · Gun control · State regulations · Mass shootings

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**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s10935-021-00622-7>.

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## Introduction

Over the last decade, tragic events such as the mass shootings that took place in Newtown, Connecticut in 2012, and San Bernardino, California in 2015, have called attention to the U.S. gun debate. Americans on one side of the debate have argued that gun owners should be permitted to carry guns in places such as churches, schools, and airports for their safety and that of their communities (Frum, 2017; Gorman & Gorman, 2016). On the other side, Americans have argued that certain types of firearms should be banned in order to reduce gun violence (Santaella-Tenorio, Cerda, Villaveces, & Galea, 2016). Although Congress has struggled to reach a consensus on the gun debate, gun sales have skyrocketed following some of these events (Childress, 2013; Liu & Wiebe, 2019).

While the number of federal background checks on guns sold has gradually increased over time, spikes in gun sales have been linked to highly publicized mass shootings or legislative attempts to restrict gun access. For example, scholars estimate that three million additional guns were sold in the five months after the mass shooting in Newtown, Connecticut (Levine & McKnight, 2017). With two-thirds of U.S. gun owners citing protection as the main reason for purchasing a gun, many believe that this spike in gun sales was triggered by individuals who were concerned for their personal safety after the mass shooting (Jones & Stone, 2015; Pew Research Center, 2017). News reports and studies have also cited a fear of gun restrictions leading to a spike in gun sales with the passage of gun control legislation (Aisch & Keller, 2015; Stroebe, Leander, & Kruglanski, 2017; Studdert, Zhang, Rodden, Hyndman, & Wintemute, 2017). Despite the widespread concern of an increase in gun exposure following these events, scholarly evidence in this area of research is extremely limited due to a lack of data and funding (Hemenway, 2017). Many existing reports and studies rely on federal background checks from the National Instant Criminal Background Check System (NICS) as a proxy for guns sold in the U.S. (Castillo-Carniglia et al., 2018; Jones & Stone, 2015; Wallace, 2015). Earlier studies, however, have identified a number of flaws with these data leading to an undercount estimate in the number of guns actually sold across the country (Bellisle, 2018; Sumner, Layde, & Guse, 2008). The following question remains unanswered: do gun control laws have the same unintended consequences on gun sales as high profile mass shootings?

This paper seeks to address this gap in the literature by examining whether the rise in gun sales is associated with proposed gun control legislation and how this varies by gun owner. We first review relevant research to understand the link between gun sales, high profile mass shootings, and proposed gun control legislation. We then describe firearm transaction data for this study drawn from the Massachusetts Firearms Records Bureau (FRB). We focus on the sale of handguns because they are used in two-thirds of all murders and non-negligent manslaughters and, therefore, have a tremendous impact on gun violence in the U.S. (Pew Research Center, 2019). We then explore three key research questions: First, we examine the association between handgun purchases and high profile mass shootings while controlling for seasonal effects and time. Second, we examine

the association between handgun purchases and the Massachusetts gun legislation while controlling for seasonal effects and time. Finally, we examine whether there are any significant changes in handgun purchases following high profile events between different types of gun owners while controlling for seasonal effects and time.

## Mass Shootings and Gun Sales

On December 14, 2012, an armed 20 year old, Adam Lanza, walked into the Sandy Hook Elementary School and fatally shot 20 children between 6 and 7 years old, as well as 6 adult staff members in Newtown, Connecticut. Three years later, Syed Rizwan Farook and Tashfeen Malik opened fire on a staff gathering at a social services center in San Bernardino, California on December 2, 2015. Using semiautomatic pistols and two rifles, they shot and killed 14 people and wounded 22 others (Schuppe, Chuck, & Kwong, 2015). Although each event involved different individuals and took place on opposite sides of the country, both of these events were widely covered by national media outlets and involved a large number of innocent people. Both events were also followed by a spike in federal background checks on firearms, according to data from the National Instant Criminal Background Check System (NICS; Dahmen, 2018; Follman, Aronsen, & Pan, 2020). With more than two-thirds of gun-owners citing self-protection as the main reason for purchasing a gun, some reports have suggested that there is a direct link between these tragic events and gun sales (Stroebe et al., 2017). However, it is unclear whether this fear of crime and/or victimization is associated with other factors such as perceived risk (Rojanasakul & Migliozi, 2016). For example, gun owners citing protection as a main reason for owning a gun did not vary significantly between those who viewed their community as safe (i.e., low perceived risk), and those who viewed their community as unsafe (i.e., high perceived risk). On the other hand, gun owners who believed that the world, generally speaking, had become more dangerous were significantly more likely to cite protection as a reason for owning a gun (Pew Research Center, 2017).

## Gun Control Legislation and Gun Sales

In addition to concerns on public safety, an increase in calls for stricter gun legislation are also hypothesized to lead to a rise in gun sales (Studdert et al., 2017). After the Newtown mass shooting, for example, federal and state policymakers began to demand gun control measures to close the loopholes in existing gun legislation (Aisch & Keller, 2015). The Speaker of the Massachusetts House of Representatives, for example, examined the State's already stringent gun law. The Speaker appointed local policymakers and practitioners to a committee to identify best practices and to determine what improvements could be made to the state law (Massachusetts Committee to Reduce Firearm Violence, 2014). On February 3, 2014, the committee delivered its report to the Speaker and the recommendations drew both

support and criticism from gun control and gun rights advocacy groups. Gun control advocates, for example, criticized the report for not restricting the number of firearms that a given individual could purchase each month and for not restricting magazine capacity for some types of weapons (Metzger, 2014). Gun rights advocates argued against recommendations that they believed unfairly targeted gun owners. For example, they argued against giving licensing authorities the option to deny someone a firearms' license if it was determined that they were unsuitable according to the discretion of the licensing authority. They argued that the legislation should instead focus on gun safety training across the state (Annear, 2014).

Nevertheless, the Speaker of the House proposed a new law on May 27, 2014 that incorporated many of the recommendations presented by the committee. Almost two years after the mass shooting in Newtown, Connecticut, the Massachusetts Governor signed House Bill 4376, "An Act Relative to the Reduction of Gun Violence," on August 13, 2014 (Schoenberg, 2014). The new law, the Massachusetts Gun Violence Reduction Act of 2014, included a number of changes and requirements for new and existing gun owners and strengthened some areas in the existing gun legislation. First, the new gun law made changes to firearm regulation by adopting new gun licensing procedures that gave additional discretion to licensing authorities to deny licenses to individuals. Second, the new law introduced new requirements to conduct background checks for firearms sold at gun shows and private sales. While the existing Massachusetts gun law already had laws aimed at reducing firearm violence, it included penalty enhancement provisions for certain offenses committed with a firearm. The new law also encouraged statewide efforts to address suicide awareness and prevention including training for physicians and gun store employees. Finally, the new gun law also required each school to develop a safety plan.

Even though other states passed gun control legislation, it remained unclear whether these laws were associated with a spike in gun sales. Previous studies suggest that increases in gun sales are linked to Americans' fear of stricter gun control laws when states develop policies to reduce gun violence (e.g., Stroebe et al., 2017). For example, a New York Times report in 2016 suggested that proposed gun control legislation led in some states to a rise in gun sales based on an extensive analysis of federal background check data (Aisch & Keller, 2015). However, critics have argued that the data were misleading in estimating gun sales due to disparities in state gun legislation, inconsistencies in the data collected by the states, and missing information from unlicensed private dealers (Wintemute, 2019). However, other sources have found a strong association between gun control measures and gun sales following a U.S. presidential election. For example, gun manufacturers reported a sudden rise in the number of guns they sold following the election and re-election of former President Barack Obama in 2008 and 2012, respectively, assuming that gun owners were afraid that the newly elected president would support the passage of gun control legislation during his presidential terms (Smith, 2017). More recently, President Donald Trump's election in 2016 led to a decline in gun sales with reports arguing that individuals no longer feared gun restrictions during his term given his campaign promises in support of gun rights advocacy groups while running for U.S. President.

## Our Study

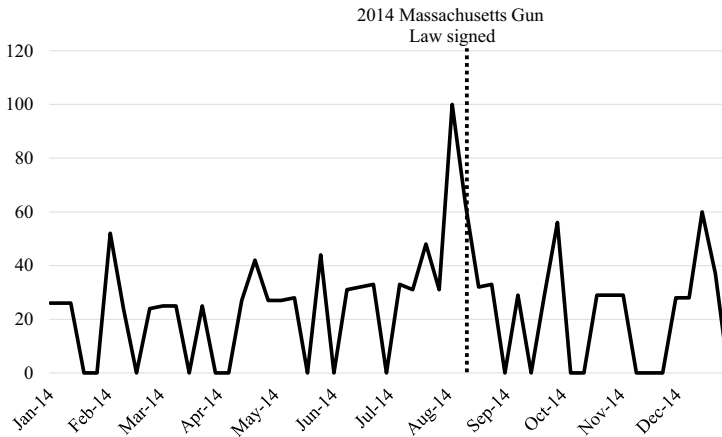
Both hypotheses—relating spikes in guns sales to concerns about public safety and fear of stricter gun control—have been tested recently. Using survey data from both existing gun owners and first-time buyers, Stroebe and colleagues (2017) tested these two hypotheses among both groups of individuals following the Orlando mass shooting in 2016 but were unable to draw any conclusions based on their findings. They suggested that the rise in gun sales following mass shootings was caused by an “atypical” group of individuals which was too small to have a significant impact on their findings. Using data on federal background checks from NICS as a proxy for firearm purchases, two other studies tested both hypotheses and found that the link between gun purchases and the fear of stricter gun control was influenced by the extensive media coverage on firearm legislation (Porfiri, Barak-Ventura, & Marin, 2020; Porfiri, Sattanapalle, Nakayama, Macinko, & Sipahi, 2019). As mentioned earlier, however, both studies were limited by their reliance on NICS data to estimate firearm purchases, which may have led to inaccurate estimates of the impact of stricter gun control.

Our study extends the literature on the impact of high profile mass shootings and gun control legislation on gun sales following concerns with public safety and fears of stricter gun control legislation. We begin by exploring changes in handguns sold in Massachusetts from 2006 to 2016 to all buyers and to first-time buyers given the different impact that these events may have had on each type of gun owner. Based on findings from national surveys, it was clear that high profile mass shootings would be likely to have a greater impact on handgun purchases made by first-time buyers than on those made by existing gun owners (Pew Research Center, 2017). The former were expected to purchase a handgun in an attempt to protect themselves due to fear of crime and/or victimization, whereas existing gun owners already had the means to do so. Gun control legislation, on the other hand, was expected to have a greater impact on all buyers assuming that all individuals shared the same fear of gun control restrictions. Due to the large disparities in gun control legislation across states, our study focused on changes in patterns of handguns sold in Massachusetts, where we explored whether there was a spike in handgun sales shortly after the passage of Massachusetts’ Gun Violence Reduction Act of 2014.

## Methods

### Data

According to Massachusetts firearm laws, buyers and sellers are required to report all firearm sales and transfers (including gifts) to the Massachusetts Gun Transaction Portal, which is maintained by the Firearms Records Bureau (FRB; McDevitt & Iwama, 2017). Massachusetts requires all weapon purchases be reported “prior



**Fig. 1** Relative frequency of weekly Google searches on “Mass gun law” in Massachusetts in 2014

to or at the point of sale” and any personal sales and/or transfers must be reported within 7 days.

We obtained data from the Massachusetts Gun Transaction Portal for all guns purchased between January 1, 2006 to December 31, 2016. All identifying information was removed from the dataset thus ensuring purchasers’ anonymity. The FRB assigned each buyer a random unique identification number, which permitted us to link multiple purchases by a buyer. While these records included the date of the transaction and the weapon type, individual-level information on the purchaser and location was not provided. We focused on any handguns purchased as well as the first recorded handgun purchased by an individual after January 1, 2006.<sup>1</sup> According to the Massachusetts Gun Transaction Portal, a total number of 559,141 handguns were purchased during our study period.

We examined temporal variations in handgun sales in relation to three events. First, we assessed the temporal association between handgun sales and two high profile mass shootings which received national coverage by various news outlets and resulted in a number of proposals to introduce gun control measures from both federal, state, and local legislatures (Astor & Russell, 2018; Studdert et al., 2017). Second, we examined the association between handgun sales and the Massachusetts Gun Violence Reduction Act of 2014. Based on earlier studies, we focused on a time when the legislation seemed to be receiving the most coverage. Other studies have shown that internet search engines can effectively retrieve information about the impact of the media (Lin, Fei, Barzman, & Hossain, 2018; Segev & Baram-Tsabar, 2010). Using 2014 trend activity data from internet searches in Massachusetts, we found searches for “Mass gun law” peaked right before the passage of the Massachusetts gun law on August 13, 2014, in contrast to the weeks before and after the

<sup>1</sup> Around 2.4 percent of records could not be linked to an individual and therefore, these records were not included in the analyses on first-time buyers.

release of the Massachusetts Gun Task Force report in February, and the proposed bill by the Massachusetts House Speaker in May 27 (see Fig. 1). Third, we focused on the impact that the passage of the new gun law had on handgun sales, given the public's increased attention to the passage of the new legislation in August of 2014.

## Statistical Analysis

We examined daily changes in firearm sales using interrupted time-series analyses, in which we assessed whether firearm sales increased shortly after each event. The model for the analysis of gun sales in the aftermath of mass shootings and gun legislation can be expressed as follows:

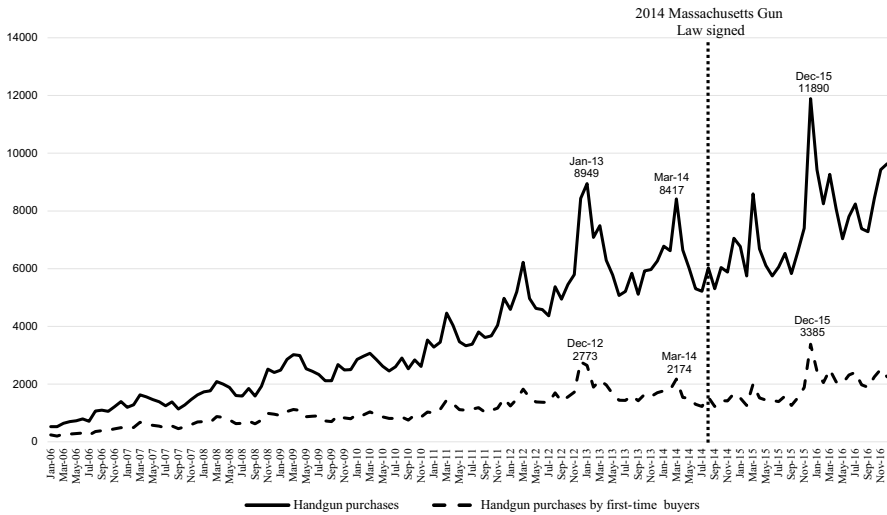
$$y_t = \alpha + \beta_1(\text{time}_t) + \beta_2(\text{time}_t)^2 + \beta_3(\text{pop}_t) + \sum \gamma(\text{day}_t) + \sum \delta(\text{month}_t) + \beta_4(\text{post event period}_t) + \varepsilon_t$$

where  $y_t$  is the number of handguns sales at time  $t$ . In this model,  $\beta_1$  represents a coefficient for linear time to detrend the data,  $\beta_2$  represents a coefficient for time-squared to capture accelerating trend, and  $\beta_3$  represents a coefficient for Massachusetts residents 21 years and older, who are eligible to purchase a handgun.  $\sum \gamma$  and  $\sum \delta$  represent a series of dummy variables capturing day of the week and month of the year, respectively.  $\beta_4$  represents the coefficient for the focal predictor variable—the post-event period. We anticipated an immediate increase in handgun sales followed by a fast rate of decay, which also is known as a “pulse function,” after each event (McDowall, McCleary, Meidinger, & Hay, 1980, p. 80). We captured this effect with a post-event dummy variable,  $\beta_4$ , which acted as our treatment period. Furthermore, with each of the consecutive models, we increased the duration of the post-event period, beginning with 7 days, and then extending it to 14 and 21 days.<sup>2</sup> We expected a significant and positive coefficient for the post-event dummy variable that captured the 7 day period following the event and, in the event we found a pulse function, we expected the coefficient should weaken as the duration of the post-event period increased in the subsequent models.<sup>3</sup>

Interrupted time series analysis requires attention to various issues (Bernal, Cummins, & Gasparrini, 2017). First, time series data are often biased by seasonality, which refers to periodic fluctuations. Gun sales are more frequent at the end of the week and during the early spring and winter months (Studdert et al., 2017). As shown in the equation, all models included dummy variables to capture the day

<sup>2</sup> According to Massachusetts gun law, licensed private citizens are allowed to transfer firearms between themselves, provided the state is notified of the sale within 7 days and that the individuals can legally possess the firearm(s) being transferred with the license in their possession (McDevitt & Iwama, 2017). Because licensed citizens must enter the information on the gun transfer in the Massachusetts Gun Transaction Portal within 7 days, we selected this timing in order to include handguns sold and recorded within this 7 day period.

<sup>3</sup> In the supplementary tables, we included subsequent models up to 10 weeks after each event to capture long-term impacts (see tables S1 and S2).



**Fig. 2** Total number of monthly handgun purchases by all buyers and first-time buyers from January 2006 to December 2016

of the week and the month in a year, with Sunday and December omitted as the reference categories. Second, time series data requires attention to nonstationarity, a condition in which statistical parameters are not independent of time. Because our use of the Dickey–Fuller test revealed that the dependent variables were generated by a trend stationary process, we controlled for linear time. We also include a trend-squared variable to capture the rising trend of handguns sold over the 11-year period. Finally, time-series data are prone to serial correlation, which refers to the correlation between values of a time series and prior values of the same series. In order to test for serial correlation, we examined scatterplots of contemporaneous and lagged values of the outcome variables, and we used the Durbin–Watson test for this purpose as well. We found no serial correlation detected for handgun sales. Using a negative binomial regression estimator with robust standard errors, we estimated the association between handgun sales and antecedent events. This model is appropriate when analyzing non-negative integers in which over dispersion may be present. We estimated all analyses using the statistical software package STATA/SE 16.0 for Mac.

## Results

### General Handgun Sale Patterns

Before we begin to discuss the results from the time series analyses, we examined the general patterns of handgun sales. As shown in Fig. 2, there was a dramatic rise in handgun sales during certain months. For example, between November 2012 and December 2012, the number of handguns purchased increased by about 45%



**Table 1** Negative binomial estimates: Massachusetts handgun sales and high-profile events ( $N=4018$ )

Variable	All buyers	First-time buyers
<i>Newtown mass shooting</i>		
7 days after mass shooting	0.512 (0.126)***	0.672 (0.129)***
14 days after mass shooting	0.507 (0.090)***	0.627 (0.092)***
21 days after mass shooting	0.455 (0.074)***	0.575 (0.076)***
<i>San Bernardino mass shooting</i>		
7 days after mass shooting	0.379 (0.126)***	0.637 (0.128)***
14 days after mass shooting	0.419 (0.090)***	0.661 (0.092)***
21 days after mass shooting	0.450 (0.075)***	0.658 (0.076)***
<i>Massachusetts gun legislation</i>		
7 days after law passed	0.458 (0.127)***	0.471 (0.132)***
14 days after law passed	0.136 (0.091)	0.150 (0.096)
21 days after law passed	0.017 (0.075)	0.032 (0.079)

Standard errors are in parentheses

\* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$

from 5796 to 8433. At the same time, the number of handguns purchased by first-time buyers increased by about 61% from 1719 to 2773. This spike in gun sales matched national-level patterns in the number of background checks, was connected to the Newtown mass shooting, and was associated with President Obama's executive order expanding background checks for all firearm purchases (FBI, 2019). From November and December 2015, the total number of handguns purchased by all buyers and those purchased by first-time buyers grew again from 7401 to 11,890 and from 1886 to 3385, respectively. Again, this 60–80% increase was linked to widespread concern following the San Bernadino, California mass shooting, which was consistent with the spike in gun sales across the country (Winter & Blankstein, 2016).

## Handgun Sales and Mass Shootings

Table 1 begins to explore handgun purchases after the two high profile mass shootings. The table shows the negative binomial coefficients with robust standard errors for handguns sold following the Newtown and the San Bernardino mass shooting. Net of control variables, the parameters following both mass shootings are positive and statistically significant. The coefficients for all buyers in Table 1 indicate that the expected number of handguns sold 7 days after the Newtown mass shooting increased by more than 67 percent ( $e^{.512}$ ). However, this effect dissipates over time in the following days as the coefficients for 14 and 21 days drop from 0.507 to 0.455, respectively. The number of handguns sold to first-time buyers also increases by about 96 percent following the Newtown mass shooting according to Table 1, but this effect dissipates in a similar fashion. The coefficients indicate a statistically

significant increase in handguns sold followed by a decay and as expected, the effect on first-time buyers is much larger in the first week after the event.

Turning to handguns purchased after the San Bernardino mass shooting, the number of handguns sold to all buyers also increased by about 46 percent ( $e^{.379}$ ) 7 days after the tragic event. While this association is statistically significant and similar to the observed aftermath of the Newtown mass shooting in December of 2012, the coefficients for 14 and 21 days post-event are 0.419 and 0.450, respectively, which indicate a continued rise in handguns purchased in the weeks following the San Bernardino mass shooting. A similar pattern is found with handguns purchased by first-time buyers following the mass shooting with a slight increase from 7 to 21 days after the mass shooting event.

### Handgun Sales and Gun Legislation

Next, we examine handguns purchased following the passage of the Massachusetts gun legislation in Table 1. Although the Massachusetts Gun Violence Reduction Act of 2014 was not effective until January 1, 2015, the Massachusetts Governor signed the bill on August 13, 2014. Despite having some of the strictest gun regulations in the country, the Massachusetts legislation sought to address some of the concerns from both sides of the U.S. gun debate on gun violence. Because most of the public's attention was drawn to the passage of the legislation that included provisions such as increasing discretion to police chiefs to deny firearm licenses, developing a new state criminal background check system, and enhancing criminal penalties for firearm-related offenses, we examined whether handguns sold increased after this public event.

Net of control variables, the results in Table 1 indicate that the week after the legislation was signed, the expected number of handguns purchased by all buyers increased significantly by about 58 percent ( $e^{.458}$ ). As anticipated, this association dissipated quickly over time. The coefficients 14 and 21 days after the passage of the legislation were 0.136 and 0.017, respectively, and neither was statistically significant. Turning to the coefficients for first-time buyers in Table 1, the expected number of handguns purchased by first-time buyers increased significantly by about 60 percent ( $e^{.471}$ ), but the magnitude of the coefficient decreased dramatically by about 45 percent from 7 to 14 days after the passage of the gun law. The coefficient for 21 days after the event was much smaller and was not statistically significant.

### Discussion

Research on the topic of gun violence and gun policies has been subject to considerable debate in the areas of criminology, economics, health, law, and public policy (Castillo-Carniglia et al., 2018; Gorman & Gorman, 2016; Jones & Stone, 2015; Miller, Hepburn, & Azrael, 2017; Wilkinson & Fagan, 1996). Most of this research has focused on the impact of guns on homicide and suicide, non-fatal injuries, and the overall costs of gun violence. To our knowledge, no other study has examined

changes in handgun sales among different types of buyers (e.g., first-time vs. repeat buyers) in the immediate aftermath of mass shootings and the passage of gun legislation. While news reports and other studies have explored increasing gun sales following highly publicized mass shootings and calls for gun control legislation, many of these reports and studies are based on NICS data, which provides a national perspective, but has been proven to be unreliable (Bellisle, 2018; Sumner et al., 2008).

Our study examined changes in Massachusetts gun sales following high profile mass shootings and gun control legislation. Using data on handguns sold in Massachusetts to all buyers and first-time buyers, we tested whether the concern for public safety or fear of gun control restrictions had a significantly larger impact on increasing gun sales. First, we examined the impact of high profile mass shootings on handgun sales. Earlier studies predicted high profile mass shootings would have a larger impact on handguns purchased by first-time buyers compared to repeat buyers due to concerns for public safety (Stroebe et al., 2017). As non-gun owners, these individuals were expected to be more concerned about their public safety than current gun owners. Our findings indicated that first-time buyers were more likely to purchase a handgun following high profile mass shootings, which confirmed that these individuals were primarily concerned about their safety. However, the coefficients pointed in two different directions after 7-days post-purchase. Although it was unclear why each event made a different impact on handgun sales after the initial “pulse function,” our finding suggested that mass shootings are unique events. In addition to the different motives, location, and other characteristics of the event, it is possible that media coverage and the clustering of mass shootings within a time period may have generated greater concern among the public, especially first-time buyers. Studies exploring the “contagion” effect, wherein the occurrence of one mass shooting increases the likelihood of another in the near future, as well as the impact of media coverage on mass shootings, have found that these effects may increase the likelihood and fear of future mass shootings (Mendl & Ivy, 2017). Future studies should consider exploring this further to better understand how mass shootings impact future events.

Second, we examined the impact of gun control legislation on handgun sales. Previous studies have shown that gun control restrictions have a greater impact on the rise in gun sales and this association is found to be influenced by media coverage. However, the variation across different types of buyers remains unclear. We hypothesized that gun control legislation would lead to a fear of gun control restrictions by both current and new gun owners (Porfiri et al., 2019, 2020; Stroebe et al., 2017). Our findings indicated that gun control legislation in Massachusetts had a similar impact on all types of buyers, who fear that stricter gun control measures would prevent them from purchasing a handgun in the State. Although its gun legislation was not scheduled to take effect until January 2015, internet trends suggest that associated media coverage took place during the ceremonial signing event of the State’s Gun Violence Reduction Act in August 2014. These results support findings of previous studies that media coverage influences the association between gun sales and gun control legislation and raises fear among both current and new gun owners (Porfiri et al., 2019, 2020).

As hypothesized, the mass shootings were followed by a significant increase in handguns purchased one week after each event. However, two findings are worth noting. First, the coefficients 14 and 21 days after each event points to different patterns. We attributed this finding to the expected adoption of gun control legislation following the Newtown mass shooting; this was in contrast to efforts in Massachusetts following the San Bernardino mass shooting where adoption of stricter gun control measures failed immediately (Markey, 2015). Second, the number of handguns purchased by first-time gun owners continues to increase 2 and 3 weeks after the San Bernardino shooting while it decreases after the Newtown mass shooting. Although both events received significant media attention resulting in spikes in gun sales across the country, the San Bernardino shooting was different in that it was a domestic terrorist attack the took place after another terrorist attack in Paris in November 2015. This widespread attention to terrorist attacks within a month of each other may have had a larger impact on residents' fear of public safety particularly among first-time buyers in 2015, compared to 2012 when the Newtown mass shooting took place. However, the 2015 Paris attacks, which included a series of terrorist attacks in France on November 13 and 14, did not lead to a significant increase in handguns purchased in the U.S. the week after the event took place. In supplementary analysis, we estimated the negative binomial coefficients following the Paris attacks and the results were not statistically significant for all handguns purchased the week after the attack net of control variables (see Table S3). Yet, the accumulation of events, starting with the Paris terrorist attack and ending with the call for gun regulations by former President Barack Obama following the San Bernardino mass shooting, may have led to a significant rise in handgun purchases in the following weeks (Aisch & Keller, 2015). It is important consider how these and future events may impact firearm sales in order to prevent a rise in gun exposure.

Our findings have several important implications for research on the relationship between gun sales, mass shootings, and gun control legislation. First, it is clear that research in this area has been limited by the availability of data and lack of funding (Hemenway, 2017). However, it is important to identify new sources of data in order to better understand the impact of exposure to guns and gun violence. For example, the magazine *Mother Jones* has been collecting data and information on mass shootings since 1982 (Follman et al., 2020). This source of information may prove to be valuable as we begin to explore whether media coverage of mass shootings has unintended consequences, such as those attributable to the “contagion effect,” which suggests that widespread media coverage of mass shootings leads to increased gun ownership (Mendl & Ivy, 2017). Second, our study revealed that high profile mass shootings with a large number of fatalities have a unique impact on different types of gun owners. It is important to examine these events in more detail and to identify ways to prevent these incidents from reoccurring given the unique characteristics of each event. Finally, firearm purchasing behavior was not only associated with mass shootings but was also motivated by legislative changes intended to reduce gun availability. Policymakers should consider how to frame the passage of new gun control legislation to the public. If, as was the case in Massachusetts, legislative change is preceded by an increase in the sales of firearms, legislators may want to consider raising public awareness to inform concerned citizens about the

actual impact of the legislation, prior to its enactment. It appears from Massachusetts and other states that the public is frequently exposed to misinformation about the impact of pending firearm legislation. Some of the misinformation comes from local groups engaged in the gun debate focused on their point of view, which may be factually inaccurate. In Massachusetts, a local National Rifle Association affiliate told members and legislators that the State's legislation would result in entire communities where no resident would be able to purchase a firearm, a claim that proved to be dramatically inaccurate (McDevitt & Iwama, 2017). Some local residents may also be misinformed by national news that focuses the public's attention on public safety. The fact that these spikes in firearm purchases are brief indicates that a short reflection period between high profile mass shootings and the passage of gun control legislation might significantly reduce the number of firearms purchased.

Our study addressed challenges found in previous research, but also faced certain limitations. First, our study collected data from Massachusetts, which has one of the most restrictive firearm licensing processes in the U.S. and, consequently, may not be generalizable elsewhere. For example, the data are based on a number of required elements that must be collected following the purchase, sale, and/or transfer of a firearm. All state licensed shops are trained by local state officials on how to use the transaction portal and collect the information following the purchase and/or sale of firearms (McDevitt & Iwama, 2017). These regulations and other features regarding the licensing process in Massachusetts set the state apart from the other states in terms of firearms data and information. However, the data are also suspect to missing information. For example, all residents are asked to report information from private sales and/or gifts, but there may be an unknown number of firearm sales that are not reported following these types of transactions. Finally, we chose specific mass shootings which had a significant impact across the country, and as such would have had an equally significant impact on gun sales in Massachusetts. Future studies should consider exploring the impact of gun control measures passed in other states. It is important to develop a better understanding on patterns of gun sales in other states following specific gun control measures in order to identify possible changes in a community's exposure to guns. News reports have also suggested that changes following elections have a significant impact on gun sales, as the total number of guns sold decrease after it becomes clear that the new political party in leadership will not pass any gun control measures. These factors should be carefully examined in future research given the detrimental impact that high profile events may have on gun sales as states continue to debate ways to reduce gun violence.

**Acknowledgements** The authors thank the staff at the Massachusetts Firearms Records Bureau for providing the study data.

**Funding** The data for the study was obtained from the Firearms Records Bureau (FRB) under a research grant from the Massachusetts Executive Office of Public Safety and Security (EOPSS) pursuant to funds appropriated in Chapter 119 of the Acts of 2015 (MA Legislation-8000-1002). The contents of the study are solely the responsibility of the authors and do not necessarily represent the official views of the funding agency. The funding agency had no role in the study design; in the analysis and interpretation of data; writing of the manuscript; and in the decision to submit the manuscript for publication.

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare they have no conflicts of interest.

**Ethics Approval** The dataset was stripped of all identifying information and could not be linked back to subjects from who the information was originally collected from. The de-identified data was exempt from Northeastern University Institutional Review Board approval.

**Informed Consent** For this type of study, formal consent is not required.

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