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Legal Firearm Sales at State Level and Rates of Violent Crime, Property Crime, and Homicides

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ARTICLE INFO

Article history:
Received 19 January 2022
Received in revised form
23 June 2022
Accepted 15 August 2022
Available online xxx

Keywords:
Background checks
Firearm sales
Firearms
Homicides
NICS
Violent crime

ABSTRACT

Introduction: The effects of firearm sales and legislation on crime and violence are intensely debated, with multiple studies yielding differing results. We hypothesized that increased lawful firearm sales would not be associated with the rates of crime and homicide when studied using a robust statistical method.

Methods: National and state rates of crime and homicide during 1999-2015 were obtained from the United States Department of Justice and the Centers for Disease Control and Prevention. National Instant Criminal Background Check System background checks were used as a surrogate for lawful firearm sales. A general multiple linear regression model using log event rates was used to assess the effect of firearm sales on crime and homicide rates. Additional modeling was then performed on a state basis using an autoregressive correlation structure with generalized estimating equation estimates for standard errors to adjust for the interdependence of variables year to year within a particular state.

Results: Nationally, all crime rates except the Centers for Disease Control and Prevention–designated firearm homicides decreased as firearm sales increased over the study period. Using a naive national model, increases in firearm sales were associated with significant decreases in multiple crime categories. However, a more robust analysis using generalized estimating equation estimates on state-level data demonstrated increases in firearms sales were not associated with changes in any crime variables examined.

Conclusions: Robust analysis does not identify an association between increased lawful firearm sales and rates of crime or homicide. Based on this, it is unclear if efforts to limit lawful firearm sales would have any effect on rates of crime, homicide, or injuries from violence committed with firearms.

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https://doi.org/10.1016/j.jss.2022.08.004

Introduction

The effects of firearm ownership are widely debated in both the social science and medical literature. Given the lack of universal firearms registration in the United States, no method exists to precisely quantify legal firearm ownership, although a 2015 study estimated the number to be 265 million weapons.[1] Important questions exist regarding any potential effects of legal firearm ownership and purchases on crime. Prior studies concerning the potential risks and benefits of firearms ownership have yielded conflicting results. Some suggest an increased risk of death and injury,[2-8] whereas others suggest a significant protective effect.[9-12] Further studies suggest no significant changes in violent crime,[11,13-16] whereas others suggest a mixed effect.[17-19] These inconsistent results could hinder the creation of informed policy decisions. Because of the lack of specific data on firearm sales, multiple prior studies have suggested the use of firearm background checks as a surrogate marker for legal firearm sales.[3,13,20,21] The analysis of this surrogate marker allows for the investigation of trends, which might be affected by firearm purchases.

Given the inconsistency of prior studies, our group investigated whether legal firearms sales, using the surrogate marker of firearm background checks, are associated with changes in publicly reported crime or homicide rates. This is an important consideration, as some are concerned that increased firearm sales might both directly and indirectly lead to increases in crime and homicide. We hypothesized that increased lawful firearm sales would not be associated with rates of crime and homicide. However, as always, it is important to remember that association does not necessarily equate with causation. Robust conclusions in this area may help better inform policy decisions on firearms ownership as well as injury and crime prevention.

Methods

Our work was a retrospective analysis of national- and state-level publicly available data on crime and firearm sales during the study period of 1999-2015. The aim was to assess any relationship between legal firearm sales and rates of violent and nonviolent crime on both national and state levels. This study was reviewed by the Institutional Review Board of the Mayo Clinic and was determined not to constitute human subjects research, as it uses only publicly available deidentified data. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Databases used

For the study period from 1999 to 2015, data regarding national- and state-level crime rates and public health statistics on homicides were collected from two publicly available sources, specifically the US Department of Justice Uniform Crime Reporting (UCR) program and the US Centers for Disease Control and Prevention (CDC) Web-Based Injury Statistics Query and Reporting System. The UCR was established in 1929 and collects information on both violent and nonviolent crime reported to law enforcement agencies. For the purpose of our study, crime data were obtained both nationally and at the state level, identifying the rates of overall violent crime, murder, robbery, rape, aggravated assault, overall property crime, burglary, larceny, and vehicle theft.[22] CDC public health data were obtained both nationally and for individual states for the rates of both homicides and firearm homicides.[23]

In the United States, no central records are available regarding legal firearms sales. Therefore, as a surrogate for legal firearm sales, data from the National Instant Criminal Background Check System (NICS) was obtained from the US Federal Bureau of Investigation.[24] The NICS system was established under the Brady Handgun Violence Prevention Act of 1993 and mandates gun dealers who have a federal firearms license (FFL) to perform an instant background check before the transfer of a firearm to an individual. This system became active in the latter part of 1998 and is used by federally licensed firearm dealers to perform background checks when completing transactions involving the legal sale of new or used firearms to individuals. The system aggregates information from a variety of sources to ensure that the possession of the firearm by the purchaser is not in violation of the law. A FFL is also allowed to run a background check to facilitate private firearms sales between individuals but is not obligated by a federal requirement to do so. To establish a rate of firearm background checks per 100,000 population, the raw number of NICS transactions was divided by the national or state population as determined by the CDC for the same year.

Statistics

Data were analyzed using R (R Foundation for Statistical Computing, Vienna, Austria). To analyze national-level data, generalized linear modeling was performed using the log rates for crime and public health variables *versus* the year and log rate of NICS checks performed. Initial state-level analysis was then performed using a similar model but accounting for year, log rate of NICS checks, and state. Following this, we repeated our state-level analysis implementing an autoregressive 1 (AR1) correlation structure using generalized linear modeling with generalized estimating equation (GEE) estimates for the standard errors using the "geeM" package. The AR1 structure was chosen, with the assumption that datapoint correlations were the highest between adjacent years, and the degree of correlation decreased as the time interval increased. This more advanced model enabled us to account for the interdependence of crime, homicide, and purchase rates from year to year with a particular state and is similar to a model we previously used in our study of the effect of concealed carry legislation on crime rates.[14] Further GEE analysis using exchangeable and independence structures was also undertaken to ensure our chosen structure had the best overall fit. The decision was made not to pursue weighting by population. A $P < 0.05$ was defined a priori to denote statistical significance.

Results

Over the study period, complete yearly data were available for the United States in aggregate, as well as for each individual state and District of Columbia for all UCR, CDC, and NICS datapoints. A total of 12 datapoints encompassing the rates for UCR Total Violent Crime, UCR Murder, UCR Robbery, UCR Rape, UCR Aggravated Assault, UCR Total Property Crime, UCR Burglary, UCR Larceny, UCR Vehicle Theft, CDC Homicide, CDC Firearm Homicide, and NICS Checks. This resulted in 204 national-level and more than 10,000 state-level discrete data points for further analysis.

During the study period, there was a substantial increase in firearm sales, with the rate of firearm background checks more than doubling nationally over the study period from 3270 per 100,000 population in 1999 to 7200 in 2015 (Fig. 1). This increase corresponded to a total volume of 9.1 million transactions in 1999, increasing to 23.1 million in 2015. Over the 17-y study period, there were a total of 224.7 million NICS transactions. Although the firearm purchase and background check rates increased, denial rates slightly decreased—from 2.2% in 1988 to 1.4% in 2015. Overall denial rates varied between 1.1% and 1.6% over the past 10 y and averaging 1.4% over the period for which the NICS system has been in existence. This average rate is somewhat lower than the historical 2.4%, which was extrapolated from data obtained from state and local sources before the existence of the NICS system.[24]

Violent crime rates and property crime rates are shown in Figures 2 and 3. Overall 22.7 million violent crimes and 163.3 million property crimes were committed nationally during the study period; however, steady decreases in the incidences of both violent and property crime throughout the United States were demonstrated. These trends in the other crime and public health variables are indicated in Figure 4. Linear modeling demonstrated significant national trends in both the increased purchase/NICS check rates and decreases in all crime variables over the study period (Table 1). Next, the state-to-state variability of specific rates was examined. Figures 5 and 6 demonstrate the interstate variability in rates at the beginning and end of the study period, respectively. Substantial variations in firearm purchase, crime, and public health rates existed between states. This variation was at times in excess of a 100-fold difference and persisted over the study period. A summary of state changes in firearm sales and crime rates is presented in Table 2. All states demonstrated increases in firearm purchase/NICS check rates over the study period. Most states also demonstrated decreases in crime rates. Supplemental Table 1 provides a detailed view of each variable per state.

Our initial analysis using national-level data using national totals was performed using generalized linear modeling with the results summarized in Table 3. When adjusted for year and NICS transaction rate, significant decreases were found in the United States rates of murder ($P = 0.01$), robbery ($P = 0.022$), rape ($P = 0.009$), overall property crime ($P = 0.001$), larceny ($P = 0.029$), vehicle theft ($P < 0.001$), and firearm homicide ($P = 0.023$) despite an increase in firearm sales transactions during this period. No significant findings were discovered in the other crime or public health variables studied (P values ranging from 0.113 to 0.590). Using this naive analysis, it might be possible to draw a conclusion that increased legal firearms sales are associated with significant decreases in many major crime categories.

After analysis of our national results, we examined state-level data using both generalized linear modeling followed

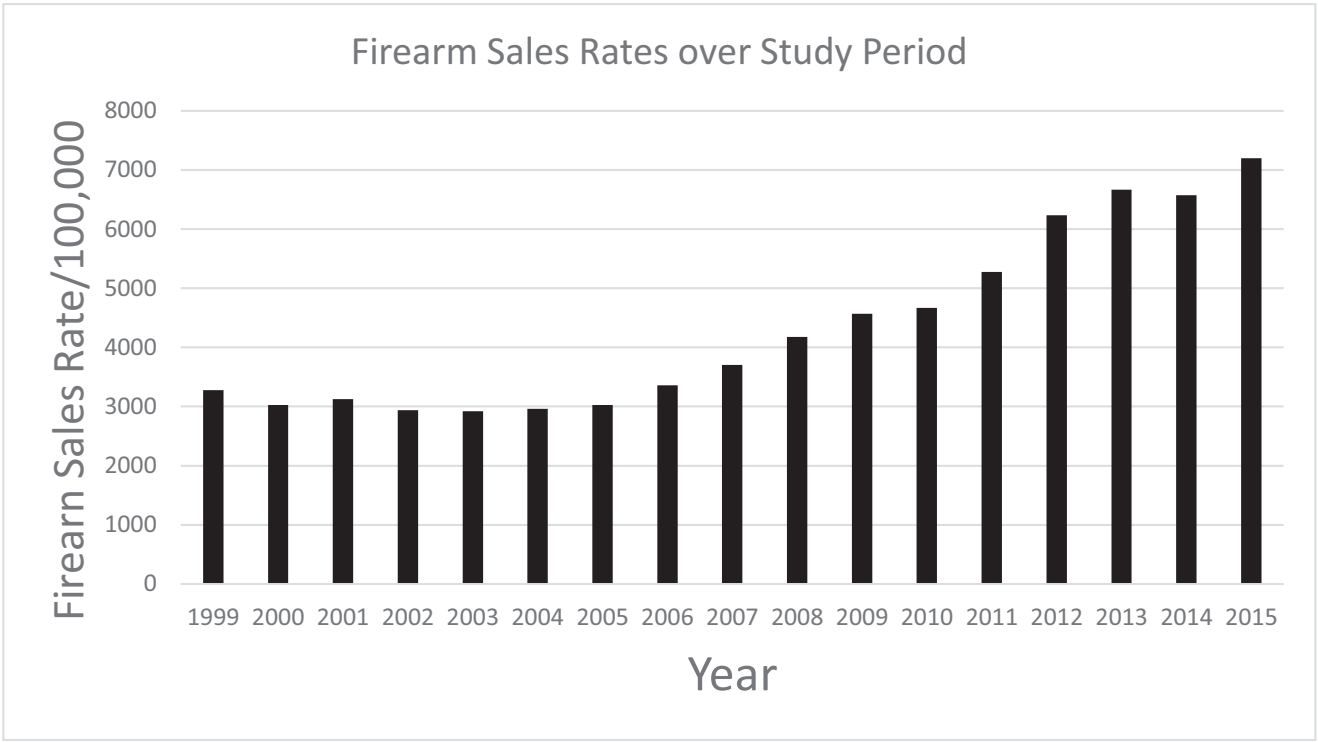

Fig. 1 – National firearm sales rates per 100,000 population over study period.

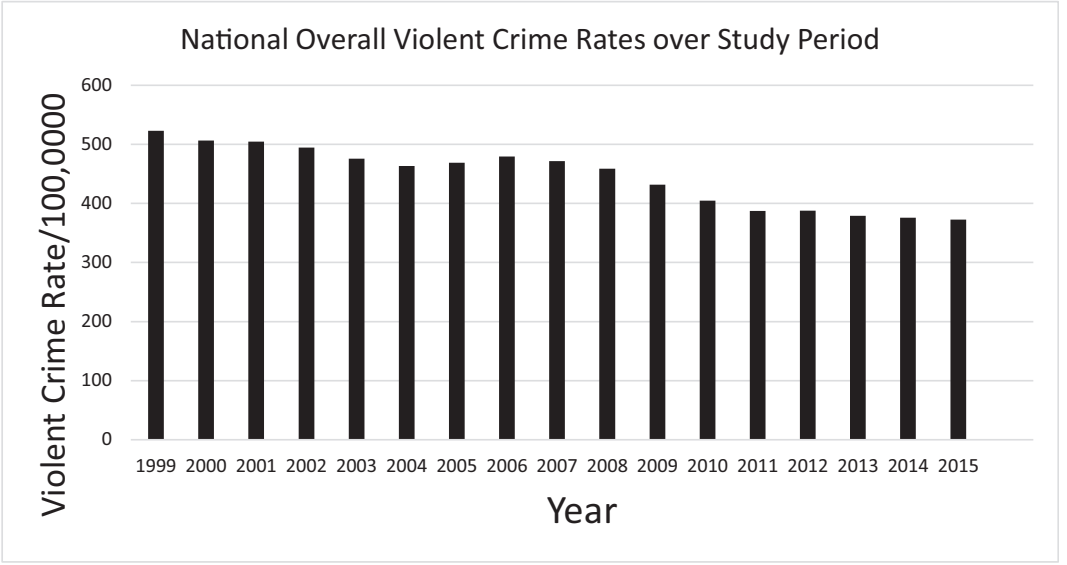

Fig. 2 – National overall violent crime rates per 100,000 population over study period.

by a more robust analysis using GEE estimates. The initial state-level analysis is summarized in Table 4. Using the simple linear modeling, after adjusting for state, year, and NICS transaction rate, significant decreases were demonstrated in murder ($P < 0.001$), burglary ($P = 0.002$), vehicle theft ($P = 0.025$), homicide ($P < 0.001$), and firearm homicide ($P < 0.001$). Increases in robbery ($P = 0.013$) and larceny ($P < 0.001$) were also demonstrated. Changes in other crime variables were not statistically significant. Overall, the fit of these initial state-level models was poor compared with the national model.

After our initial state-level analysis, we reexamined the state-level data using a more robust statistical model. Using generalized linear modeling with GEE estimates and using autoregressive covariance structure (AR1), state-level data yielded the results summarized in Table 5. This model was deemed appropriate, given that spot checks of 1-y time-lagged residuals within our data indicated a high degree of serial correlation, with estimates invariably positive and with correlations ranging from 0.18 to 0.9 and borderline or high significance. When adjusted for state, year, and NICS transaction rate, this final state-level analysis yielded results, which did not rise to statistical significance for any crime variable studied. To ensure the effects of the correlation structure chosen were appropriate, additional modeling was performed using both exchangeable and independent correlation structures. These results are provided in Supplemental Table 2. To summarize, both the exchangeable and independent

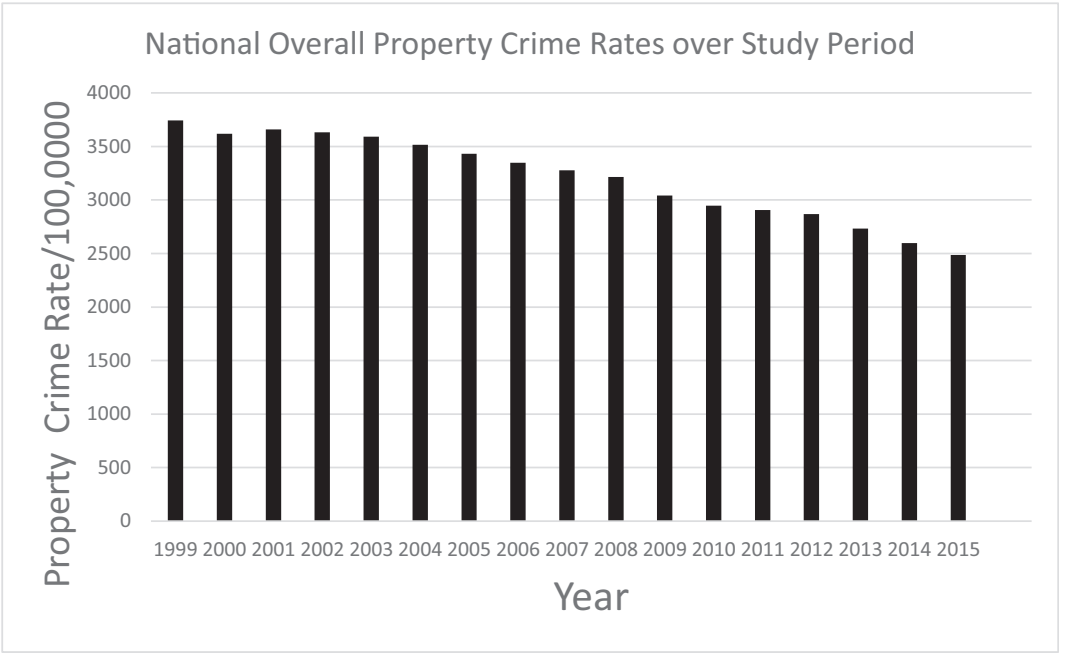

Fig. 3 – National overall property crime rates per 100,000 population over study period.

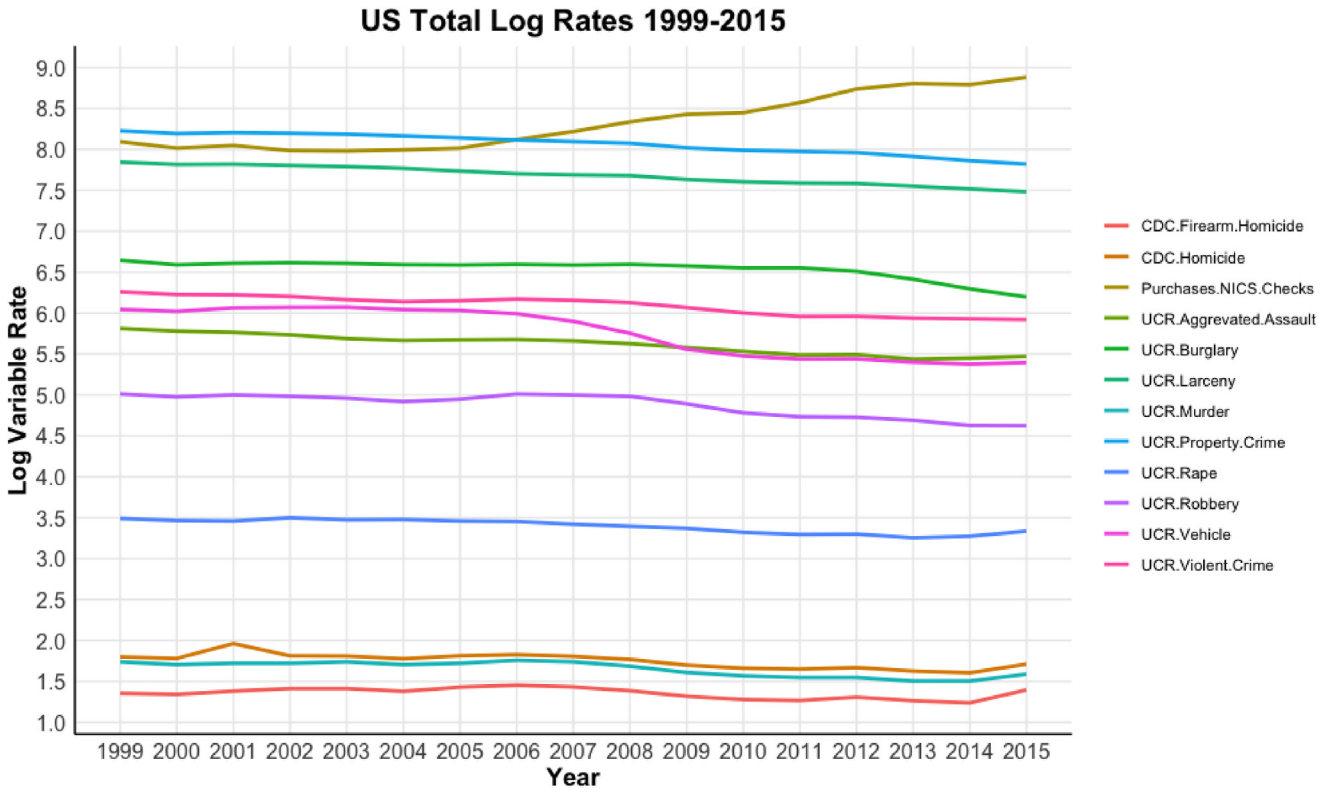

Fig. 4 – Log national variable rates per 100,000 population over study period.

structures yielded precisely identical results, including significant increases in robbery and larceny over the study period. However, these structures were rejected, and the autoregressive model was chosen to provide the most conservative estimate of the true effect as well as the best fit.

Discussion

The Second Amendment of the United States Constitution holds that "A well-regulated Militia, being necessary to the security of a free State, the right of the people to keep and bear Arms, shall not be infringed." Although the intent of this amendment has been the subject of much historical debate, the recent landmark United States Supreme Court Cases *District of Columbia et al. v. Heller* and *McDonald v. Chicago* have held that the right to own firearms is an individual right, which applies to both federal- and state-level legislation. Although the individual right to own a firearm in the United States is protected by our constitution, courts have held that this right is not unlimited in scope. Specific limitations including prohibiting possession of a firearm by felons, perpetrators of

Table 1 – National trends in variables over study period from 1999 to 2015 using generalized linear modeling.

Variable (log rate)	Estimate	Standard error	*t* value	*P*	AIC
Purchase/NICS Rate	0.0608	0.00607	10.02	<0.001*	−19.2
UCR Violent Crime	−0.02248	0.00162	−13.9	<0.001*	−64.1
UCR Murder	−0.01539	0.00249	−6.18	<0.001*	−49.5
UCR Robbery	−0.02482	0.00346	−7.18	<0.001*	−38.4
UCR Rape	−0.01529	0.00173	−8.83	<0.001*	−61.9
UCR Aggravated Assault	−0.0237	0.0013	−18.3	<0.001*	−71.7
UCR Property Crime	−0.02496	0.00138	−18.1	<0.001*	−69.7
UCR Burglary	−0.01895	0.00388	−4.89	<0.001*	−34.5
UCR Larceny	−0.02262	0.00071	−31.9	<0.001*	−92.3
UCR Vehicle Theft	−0.05466	0.00547	−10.0	<0.001*	−22.8
CDC Homicide	−0.01457	0.0028	−5.19	<0.001*	−45.5
CDC Firearm Homicide	−0.00690	0.00291	−2.37	0.032*	−44.2

AIC = akaike information criterion.
* $P < 0.05$.

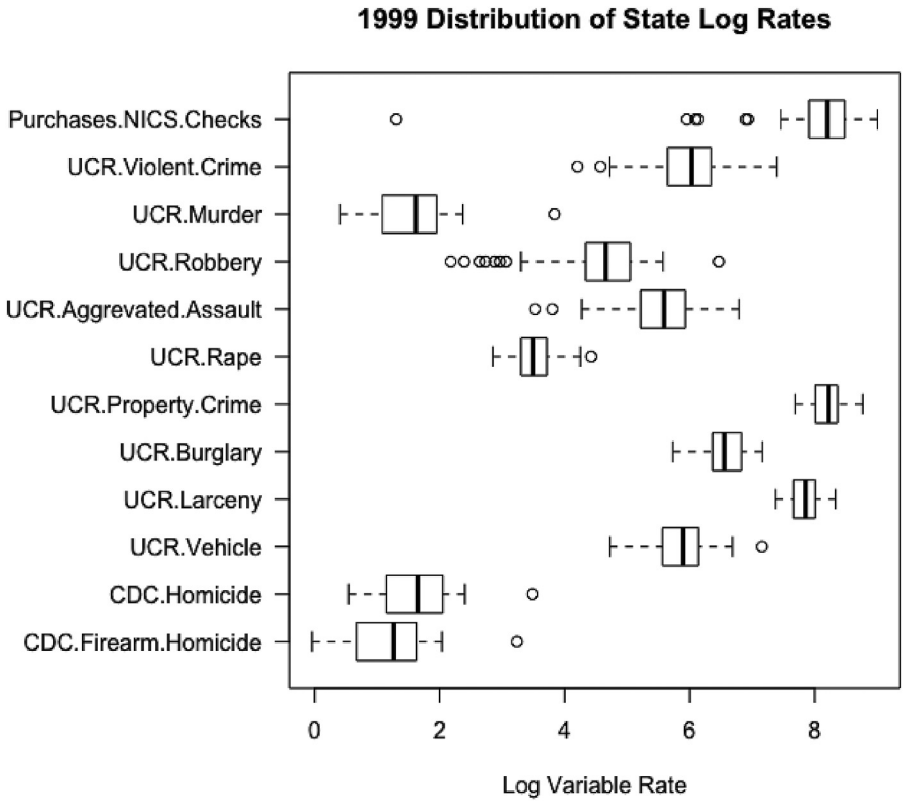

Fig. 5 – Variation between states in log rates per 100,000 population in 1999.

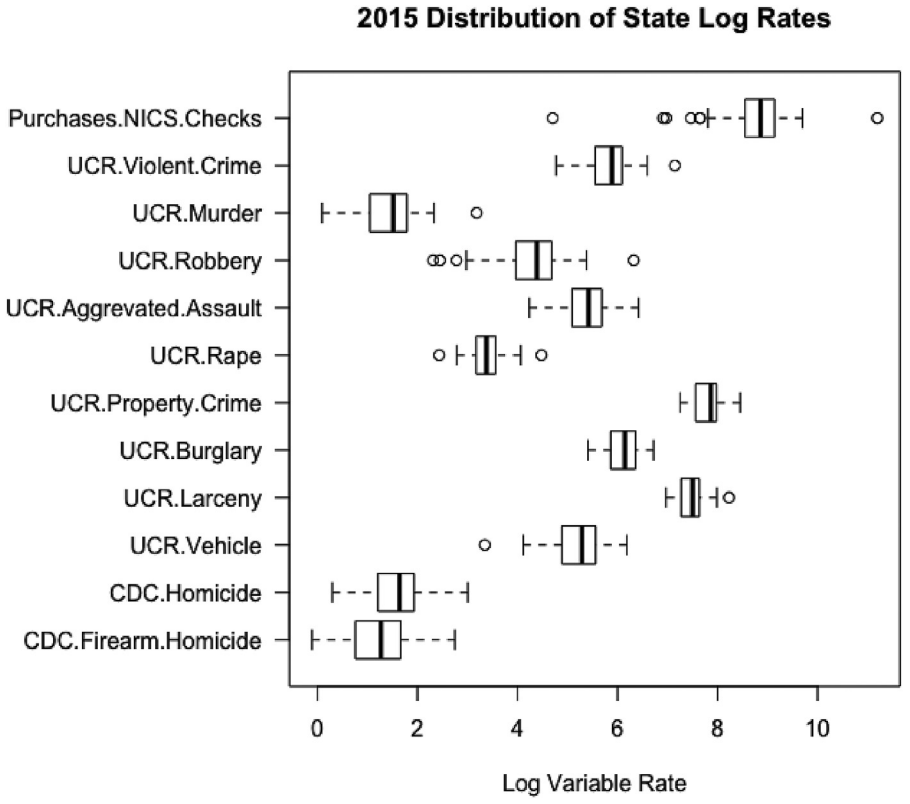

Fig. 6 – Variation between states in log rates per 100,000 population in 2015.

Table 2 – State trends in variables over study period from 1999 to 2015.

Variable	Significant increase	Nonsignificant trend increase	Significant decrease	Nonsignificant trend decrease
Purchase/NICS Rate	50 (98.1%)	1 (1.9%)	0	0
UCR Violent Crime	6 (11.8%)	6 (11.8%)	34 (66.7%)	5 (9.8%)
UCR Murder	4 (7.8%)	9 (17.6%)	18 (35.3%)	20 (39.2%)
UCR Robbery	4 (7.8%)	4 (7.8%)	34 (66.7%)	9 (17.6%)
UCR Rape	7 (13.7%)	6 (11.8%)	27 (52.9%)	11 (21.6%)
UCR Aggravated Assault	6 (11.8%)	7 (13.7%)	34 (66.7%)	4 (7.8%)
UCR Property Crime	0	0	47 (92.2%)	4 (7.8%)
UCR Burglary	0	2 (3.9%)	38 (74.5%)	11 (21.6%)
UCR Larceny	0	2 (3.9%)	47 (92.2%)	2 (3.9%)
UCR Vehicle Theft	0	2 (3.9%)	47 (92.2%)	2 (3.9%)
CDC Homicide	5 (9.8%)	9 (17.6%)	22 (43.1%)	15 (29.4%)
CDC Firearm Homicide	7 (13.7%)	12 (23.5%)	12 (23.5%)	19 (37.2%)

domestic violence, and those with significant mental illness have all been found reasonable by the legal system. Multiple individuals and medical and social science organizations, including the American College of Surgeons, the Eastern Association for the Surgery of Trauma, and American Academy of Pediatrics, have suggested additional significant limitations be placed on the availability of firearms and firearms components with the aim of decreasing violence committed with firearms.[25-33] Public support for restrictions on firearms ownership in the United States varies dramatically by gun ownership status as well as age, race, area of residence, and political ideology.[34-37]

Analysis of our large data set indicated that at a national level, increasing rates of NICS background checks (used as a surrogate for legal firearms sales) were associated with a decrease in rates of murder, robbery, rape, overall property crime, larceny, vehicle theft, and firearm homicide. An initial state-level analysis using the same generalized linear modeling demonstrated similar but somewhat conflicting results with decreased murder, burglary, vehicle theft, homicide, and firearm homicide but increased robbery and larceny. Repeating the state-level analysis using a more robust statistical analysis model did not identify an association between increased legal firearm sales/NICS checks and changes in any of the crime rates examined. This disparity only underscores the importance of choosing an appropriate and robust statistical model when examining data with important policy implications.

Given the variability of prior studies on the topic, we chose to use a robust statistical method, which would eliminate significant errors in estimating the effect and its precision. Our current data set consisted of one observation per state and the District of Columbia per study period year. For each crime and public health rate examined, a log transformation

Table 3 – Regression results using generalized linear modeling for association of NICS background checks with reported measures of crime using national-level data from 1999 to 2015.

Outcome (log rate)	Estimate	Standard error	t value	P	AIC
UCR Violent Crime	−0.1101	0.0651	−1.69	0.113	−65.3
UCR Murder	−0.2550	0.0860	−2.96	0.010*	−55.8
UCR Robbery	−0.3241	0.1253	−2.59	0.022*	−43.0
UCR Rape	−0.1790	0.0594	−3.01	0.009*	−68.4
UCR Aggravated Assault	−0.0313	0.0566	−0.55	0.590	−70.1
UCR Property Crime	−0.1658	0.0415	−4.00	0.001*	−80.6
UCR Burglary	−0.2518	0.1569	−1.60	0.130	−35.4
UCR Larceny	−0.0636	0.0262	−2.43	0.029*	−96.3
UCR Vehicle Theft	−0.6732	0.1600	−4.21	<0.001*	−34.7
CDC Homicide	−0.1464	0.1172	−1.25	0.230	−45.3
CDC Firearm Homicide	−0.2709	0.1059	−2.56	0.023*	−48.7

AIC = akaike information criterion.
*$P < 0.05$.

Table 4 – Regression results using generalized linear modeling for association of NICS background checks with reported measures of crime using state-level data from 1999 to 2015.

Outcome (log rate)	Estimate	Standard error	t value	P	AIC
UCR Violent Crime	−0.0105	0.0171	−0.62	0.539	−929.4
UCR Murder	−0.1104	0.0244	−4.53	<0.001*	−315.9
UCR Robbery	0.0418	0.0169	2.48	0.013*	−953.8
UCR Rape	−0.0041	0.0164	−0.25	0.803	−1006
UCR Aggravated Assault	−0.0392	0.0211	−1.86	0.064	−564.6
UCR Property Crime	0.0169	0.0092	1.84	0.066	−2011
UCR Burglary	−0.0368	0.0117	−3.15	0.002*	−1591
UCR Larceny	0.0528	0.0092	5.73	<0.001*	−2003
UCR Vehicle Theft	−0.0465	0.0208	−2.24	0.025*	−592.9
CDC Homicide	−0.0907	0.0200	−4.52	<0.001*	−648
CDC Firearm Homicide	−0.0858	−0.0223	−3.85	<0.001*	−435

AIC = akaike information criterion.
* $P < 0.05$.

was performed. The specific log transformed rates—UCR Total Violent Crime, UCR Murder, UCR Robbery, UCR Rape, UCR Aggravated Assault, UCR Total Property Crime, UCR Burglary, UCR Larceny, UCR Vehicle Theft, CDC Homicide, and CDC Firearm Homicide—were the variables to be predicted. The predictor variable of interest was the rate of NICS background checks as a surrogate for legal firearm sales. The "adjustment variables" were the effects of the specific state, and year considered as additive "main effects." Using these considerations, our model considered the deviations of each states' pattern of event rates from the overall pattern of event rates across states while also removing the overall state-to-state variation in mean rates and the global average year-to-year variation in these rates. The residuals were then analyzed for any association with the NICS check log rate. General linear regression with a repeated measures option that included an autoregressive correlation structure was used. This allows for the fact that state-specific yearly event rates that are close in time are highly autocorrelated, meaning that they do not provide independent observations on the association between legal firearm sale/NICS check rates and crime rates. An analysis that does not take the autocorrelation structure into account would tend to overestimate the precision of the estimates by underestimating the standard errors. In essence, the AR1 structure assumes that datapoint correlations are highest between adjacent periods, with the correlation decreasing as the time interval increases. The identical results between the exchangeable and independence correlation structures are an indication that they are essentially eliminating the main effect of the state in the analysis, yielding an inaccurate picture of the true results. In both models, the state is fit exactly as a fixed effect and the residuals within the state sum to zero. Therefore, the average pairwise correlation between pairs of years within a state is zero, and the estimated between-year correlation is also zero. In addition, both these models had higher standard errors and worse overall fit than the autoregressive model. Given this, as well as the significant correlation between rate points within states, the AR1 model provides the most conservative estimates of the true effects, despite not identifying any

Table 5 – Regression results using GEEs using autoregressive correlation structure for association of NICS background checks with reported measures of crime using state-level data from 1999 to 2015.

Outcome (log rate)	Estimate	Standard error	Wald	P	QIC
UCR Violent Crime	0.0046	0.0113	0.41	0.684	807
UCR Murder	−0.0793	0.0305	0.05	0.130	836
UCR Robbery	0.0126	0.0138	0.91	0.361	818
UCR Rape	−0.0017	0.0118	−0.15	0.883	818
UCR Aggravated Assault	0.0171	0.0161	1.06	0.288	795
UCR Property Crime	−0.0003	0.0086	−0.04	0.969	792
UCR Burglary	−0.0170	0.0145	−1.17	0.241	808
UCR Larceny	0.0120	0.0112	1.07	0.283	767
UCR Vehicle Theft	−0.0247	0.0234	−1.06	0.291	809
CDC Homicide	−0.0806	0.0454	−1.77	0.076	829
CDC Firearm Homicide	−0.0734	0.0545	−1.35	0.178	752

QIC = quasi information criterion.

significant associations between increased firearm sales and changes in the crime rates studied. The decision not to pursue weighting of data by population was made so as not to unfairly bias the results toward states with high populations and population densities. In addition, spot checks on the rates of violent crime indicated that only 1% of the models' residual variance was due to "pure error" that would be affected by state size. The remaining 99% of the residual variance would not be influenced by state size, thus statistically validating the use of equal weighting. Other potential covariates, such as poverty and unemployment, were excluded from our current analysis based on the results of a prior analysis from our group, which demonstrated no significant changes in the analysis if they were included.[14]

As indicated previously, studies from different academic perspectives on the effects of firearms on crime and violence have yielded different, often diametrically opposed, conclusions. Given this, the specifics of the studies must be considered in more detail to determine the cause of this discrepancy. To help interpret these differences, it is important to examine the methodology, population, and time frame examined in the existing research to ensure the accuracy and generalizability of the results. We will consider several examples. One important example is the landmark study by Kellermann and Reay on the effects of gun ownership in Washington state in 1986. Based on their analysis, the authors concluded that the presence of a firearm in the home did little to promote personal protection and was associated with marked increases in accidental deaths, homicides, and suicides.[2] This widely cited and often quoted study, when taken at face value, makes a compelling argument against the presence of firearms in the home. However, serious doubts have been raised concerning the methodology and veracity of these conclusions. One critical analysis of Kellermann's work points out multiple serious flaws, including the use of truncated datasets, invalid methodology, and a failure to consider other relevant literature, especially that of the social science, economics, and legal realms.[9] It is important to note that when considering other disciplines, there is no universal consensus regarding the potential effects of firearms and gun control legislation. A recent study by Berg *et al*., which examined the attitudes of expert researchers from different academic fields on the potential effects of a wide variety of gun policies demonstrates, vast differences in opinion exist.[38] When criminologists, economists and public health experts involved in research on firearms and violence were polled, each discipline reported widely different opinions on the effectiveness of a comprehensive assortment of policy proposals. These opinions varied not only based on the area of expertise of the researcher but also with respect to their nationality. This suggests that no universal consensus exists in attitudes toward gun policy and gun control efforts. This was further quantified in a recent study by the Rand Corporation investigating the magnitude and source of disagreement among gun policy experts.[39]

Another important consideration is the choice of the period studied. One recent example is the work of Levine and McKnight, which examined the effects of increased firearm sales in the wake of the Sandy Hook school shooting on accidental firearm deaths. In their study, they focus on a short time frame following Sandy Hook murders, which exhibited a spike in firearms background checks. When examining this specific period, they demonstrated an increase in the accidental firearm deaths involving children.[3] Admittedly, the authors acknowledge that given their limited time frame, they are unable to account for any long-term impact of the increased firearm sales. However, focusing on an extremely limited time frame raises the serious risk that their results may be the effect of other unstudied factors.

These critiques serve to underscore one important strength of our study. Given our use of a complete data set from multiple states over an extended period, we sought to minimize the effects of unstudied local and time-limited variables on the outcomes examined. Given the general trends toward increased firearm sales and decreased crime, it is unlikely that a short-term aberration would significantly change our overall findings. The results of studies looking at significantly limited time frames would likely be more easily influenced by other events occurring in close temporal association with the study period.

One vitally important area of examination is the overall plausibility of the link between legal firearms sales and crime. As detailed below, several studies have examined the flow of firearms from legal ownership into criminal use. In these, several conflicting points are observed, and important questions are raised. With the heterogenous results of studies examining the effects of firearm possession and ownership from a variety of academic fields and nationalities, it is possible that any true effects are minimal at best or may be primarily driven by a limited group? Given the potential for the use of firearms in the commission of crimes, should consideration be given to the specific source of firearms used for those criminal offenses? A recent survey of prison inmates demonstrated that approximately 20% were in possession of a firearm during the commission of the crime that led to their incarceration.[40] When polled regarding the source of their firearm, only 8.1% obtained the weapon from a source, which would require a background check. More the 43% of the weapons were obtained from an illicit or underground source, whereas another 25% obtained the weapon from a friend or family member. Another 17% reported other sources, including finding the weapon at the location of the crime and purchases by a surrogate (so-called straw purchases). When totaled, the vast majority of firearms used in the crimes studied were obtained from sources, which illegally circumvented the existing background check process. A study by Koper attempted to quantify specific characteristics associated with legally purchased firearms, which are eventually recovered by the police in the Baltimore, Maryland area.[41] By examining factors including buyer characteristics (race, age, gender, residence location), dealer characteristics (type, time in business, volume, distance to city), and firearm characteristics (action, caliber, size, cost), percentages recovered were calculated, and hazard ratios computed. Two factors—low-cost weapons and close proximity (<5 miles) of the sale to the city of Baltimore—demonstrated >10% rates of eventual police recovery. The author found that multiple factors increased the risk of firearm recovery by law enforcement; however, the vast majority of these factors are likely not specifically actionable, as interventions based on buyer characteristics would raise the specter of racial profiling, and

many of the firearm characteristics were also common to the most popular purchased firearms in general, specifically medium-to-large caliber semiautomatic pistols.

Significant potential insight into the varied effects is offered by Khalil in his study of the role of illegal firearms.[42] In a detailed analysis, he demonstrates that the role of firearms in crime is driven by stolen firearms rather than those possessed legally. The concept that crime is driven by those who illegally possess and use firearms rather than those who follow the law has important policy implications, including that focusing on reducing legal gun sales may have little or no effect on reducing crime. Another interesting analysis by Cook *et al.* dives deeper into this area.[43] In their analysis, they find that the median time between the illegal transaction during which potential offenders acquire a firearm and the use of that gun in a crime is just 2 mo. Given this, they suggest that more effective enforcement of laws against illegal gun transactions may be a way to rapidly decrease gun use in crime. Kovandizc *et al.* provide another compelling argument against the reduction of firearms.[11] In examining the potential effects of gun possession and prohibition, they conclude that gun bans could potentially increase gun homicide rates as criminals, whose possession is associated with an increase in firearm homicides, will likely ignore the bans.

Another potential consideration that can skew data is underreporting of events when firearms are used defensively to prevent crime. In 1995, Kleck and Gertz estimated that approximately 2.5 million defensive firearm uses per year, many of which go unreported to the police.[44] Assuming this number to be steady over our study period, this would account for 42.5 million defensive firearm uses, almost double the number of violent crimes reported and one-quarter of the nonviolent crimes. A more recent study in the American Journal of Criminal Justice further highlights these points. In 2021, Kleck revisited this issue and completed an analysis of criminal *versus* defensive firearm uses in the United States, in which he concluded that defensive firearm uses were likely seven times those of crimes committed by offenders with firearms.[45] Using recent estimates, he demonstrated defensive firearm uses likely total almost 2.9 million per year but noted this is also almost certainly an underestimate. If these defensive uses led to a decrease in the number of crimes committed and reported to the police, firearms could be responsible for significant reductions in overall reported crime.

Our study does have several significant limitations. First and foremost, as a retrospective analysis, we cannot attempt to prove causation, only association. This requires caution when interpreting our results. We were unable to identify an association between increased legal firearm sales and changes in rates of crime or homicides. It is impossible to say if this truly represents no effect or the possibility of an offsetting effect, where increased legal firearm ownership may offset increases in crime, which would otherwise occur. The effects of defensive firearm use on crime prevention are nearly impossible to quantify as many defensive firearm uses go unreported to the police. Furthermore, in many states, private sales of firearms between individuals are not regulated, and no reliable data exist to estimate their frequency.[46] As such, the overall number and rate of private firearm sales cannot be accurately estimated and thus cannot be accounted for in any analysis of the effects of firearm sales. Although some suggest the adoption of "universal" background checks involving all firearm sales transactions, including those between private individuals, the lack of firearm registration in the United States makes such proposed statutes virtually unenforceable.

Another point is our choice of end points, specifically crime rates and public health measures for homicide and firearm homicide. Although some of these measures—specifically aggravated assaults, murder, homicides, and firearm homicides—by their nature involve injury or death, many of those other end points do not specifically involve physical injury. Limiting the study of firearm violence to those that directly involve physical injury would be doing a disservice to the topic—which by its very nature involves many aspects of society. The wide-reaching effects of firearm violence, including physical and psychological injury, economic impacts for both the victims as well as society when the costs associated with criminal justice are considered, lend itself to multidisciplinary study, including the perspectives of medicine, public health, criminology, law, and economics.

Another important consideration is our choice of the UCR for crime rates in the United States. Although the UCR is a comprehensive collection of the crimes that are reported to the police, it cannot—by its very nature—consider crimes that go unreported. The National Crime Victimization Survey is another tool—also administered by the United States Department of Justice—that uses twice-yearly surveys administered to approximately 160,000 individuals and collects data including violent and nonviolent crime victimization, both reported and unreported to law enforcement. Although the National Crime Victimization Survey provides useful data in the overall study of crime and victimizations nationwide, given its representative sample methodology, it historically does not provide complete state-by-state data. As it would not allow for state-level analysis over our study period, the UCR was the only practical choice for the crime data in this study.

Furthermore, our study cannot account for the effects of illegal firearms sales transactions or the volume of stolen firearms. There is no effective way to measure these illegal acts, especially if they do not involve a direct police response or arrest. As detailed previously, these illegal transactions may have a significant association with subsequent criminal activity.

One final important limitation is the basic assumption that overall NICS background checks are a reasonable surrogate for legal firearm sales as has been described in multiple prior studies.[3,13,20,21] Since the development of the NICS database in the late 1990s, its use has expanded far beyond simple point of sale background checks for firearm purchasers. A basic analysis of NICS data reveals a large increase in the frequency of other nonsale transactions over time. In fact, during 2015, approximately 40% of the overall NICS inquiries represented nonpurchase transactions, including applications for state concealed carry permits and periodic rechecks of those who have existing permits. This number of nonsales transactions varies widely between individual states with the percent of actual sales transactions ranging from 100% to 9.1% (unpublished data derived from the NICS background check

database). Data regarding specific firearm purchase transactions, including the type of firearm purchased (handgun *versus* long-gun *versus* multiple purchases), is also available, and it is unclear if the potential crime effects might be dependent on the type of firearms purchased. Although we did not pursue these issues in our present study, further research is planned to investigate these avenues of inquiry.

Conclusions

Our study examined the potential association between legal firearm purchases (using the well-described surrogate of overall NICS background checks) and rates of crime and homicide. Naive analyses of national- and state-level data demonstrated substantially different degrees of association between increased legal firearm sales and decreases in multiple crime rates. However, these naive analyses likely paint an inaccurate and simplistic picture. A more robust analysis using state-level data did not identify an association between increased legal firearm sales and changes in rates of crime or homicide. Based on this study, when policymakers consider targets for intervention to help reduce crime and violence committed with firearms, areas other than the legal purchases of firearms should likely be considered. As this subject involves multiple levels of impact including personal, local, regional, and national characteristics, multidisciplinary research, including aspects of medicine, public health, criminology, law, and economics would likely be beneficial. In the end, it is clear that further high-quality research is needed on violence prevention and specifically violence committed with firearms. As noted in a recent analysis on sources of disagreement among gun policy experts by the RAND corporation, "collecting stronger evidence about the true effects of policies is, the researchers believe, a necessary step toward building greater consensus on which policies to pursue."[39]

Supplementary Materials

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jss.2022.08.004.

Author Contributions

M.E.H., M.C.H., K.R.B., and H.J.S. were involved in initial study design. M.E.H., M.C.H., and K.R.B. performed statistical analysis. M.E.H., M.C.H., K.R.B., M.D.Z., and H.J.S. performed statistical interpretation. M.E.H., M.C.H., and K.R.B. wrote the initial article draft. All authors were involved in the critical revision of the article.

Disclosure

The authors have no conflicts of interest to disclose.

Funding

The authors report no external sources of funding for the research.

Availability of Data

This article has not been published elsewhere and is not currently under consideration for publication elsewhere.

Meeting Presentation

A preliminary version of this article was presented at the 2020 meeting of the Western Trauma Association, February 25, 2020, in Sun Valley, Idaho.

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