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DOES DEFENSIVE GUN USE DETER CRIME?

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John Donohue has at various times served as an expert witness in litigation involving firearm regulation. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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ABSTRACT

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A data appendix is available at http://www.nber.org/data-appendix/w32108

Does Defensive Gun Use Deter Crime?

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We study the opposing deterrent and enabling effects of guns carried by law-abiding citizens on violent crime, using the location of shooting ranges as an instrument. Our incident-level data based on admittedly imperfect data from the Gun Violence Archive suggests that defensive gun use (DGU) by crime victims may decrease the probability of their injury or death, while increasing the risk of death or injury by the criminal suspects. However, in the aggregate, higher numbers of defensive gun uses—which proxies for more gun carrying and use—are associated with higher numbers of violent crimes, injuries, and fatalities among victims and suspects alike. We hypothesize that this equilibrium effect arises because more guns being carried and used by citizens produce more incentive and opportunities for criminals to acquire guns, leading to a commensurate increase in the incidence and lethality of crime. In summary, our analysis supports the conclusion that the widespread carrying and use of guns is overall more likely to enable violent crimes than to deter them.
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A full assessment of the costs and benefits of private gun ownership in the United States is a complex and broad-ranging task. At a minimum, it requires an evaluation of how private gun ownership impacts accidental deaths and injuries, suicides, homicides, assaultive firearm injuries, and crime more generally. In 2021, there were 549 accidental firearm deaths and tens of thousands of accidental firearm injuries.[1] If even 5% of the 26,328 firearm suicides were purely the product of gun availability, then another 1,300 deaths would be in the firearm cost column.

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[1]Kaufman et al. (2021) estimate that there are about 83 unintentional nonfatal injuries caused by firearms across the country for every accidental gun fatality, which would imply roughly 45,000 accidental firearm injuries in 2021. Barber and Hemenway (2011) conclude that the 45,000 accidental firearm injury figure is too high because hospital records "often miscategoriz[e] undetermined firearm deaths to adults as unintentional." (Solnick and Hemenway, 2019).

But while firearms can only generate social costs with respect to accidental injuries and suicide, private gun ownership has ambiguous implications for crime since there are many pathways through which the prevalence of guns can stimulate crime but also the possibility of crime deterrence or thwarting of criminal attacks. This paper tries to bring evidence to bear on whether the net impact on homicide from the availability of private defensive gun use offsets the substantial gun-induced costs of firearm accidents and suicides or further adds to the lethal tally.

To gain purchase on this question, we examine the Gun Violence Archive (GVA) data from 2014-2023, which allows us to observe a number of incidents where private defensive gun use is arguably protective of potential victims (thereby reducing homicide) and dangerous to attackers, thereby potentially deterring other criminal attacks or incapacitating some attackers (both of which would tend to reduce homicide). At the same time, we know that the prevalence of firearms in private hands can elevate homicides in a variety of ways, by escalating the lethal consequences of minor disputes or road rage, making guns more available to criminals via the massive levels of gun thefts that occur each year, and by impeding law enforcement in ways that can stimulate crime overall, including homicide. In this paper, we provide evidence—concededly on a selected sample that may exaggerate its effectiveness—that defensive gun use involving shooting at perpetrators is protective of potential victims and elevates perpetrator deaths, but that the overall impact of greater defensive gun use leads to more homicides. In other words, rather than offsetting the costs of firearm accidents and suicides, the net impact of private gun availability on homicides further adds to the lethal toll of firearms in the United States.

Accurately assessing the prevalence and effectiveness of defensive gun use has been an enormous challenge for researchers, leading to wildly varying estimates. In a major Second Amendment case in California, a federal judge drew on the more extreme set of estimates, stating that "there are 2.2 to 2.5 million defensive gun uses by civilians each year. Of those, 340,000 to 400,000 defensive gun uses were situations where defenders believed that they had almost certainly saved a life by using the gun." Such numbers are preposterous given that the U.S. has never had more than 26,000 homicides in any year, but they highlight the dangers of surveying rather small samples for politically charged and very low probability events, and then extrapolating to the entire U.S. population (Hemenway, 1996). The much larger and more methodologically sound National Crime Victimization Survey (NCVS) yields estimates on defensive gun use that are more than an order of magnitude less than the above figures (with no information on any lives saved), but NCVS data is not well-suited for use at a sub-national level, which prevents its use in our project.

Those using guns defensively are not a random sample of Americans, so simply observing higher or lower deaths or injuries among these gun users is not illuminating on the causal impact of gun ownership and use. Defensive gun users could be individuals at greater risk of victimization—perhaps procuring weapons because they live in more dangerous areas or have specific enemies or are targets of threats. Conversely, these gun users could have attributes that would otherwise tend to protect them from crime victimization—perhaps being more affluent, older, more vigilant against crime, or more likely to have military training. In this paper, we exploit spatial variation in crime, police-verified defensive gun uses, and shooting ranges to identify the effect of defensive gun use on crime. Since it is entirely possible that gun prevalence and use could have different effects on the individual users versus the overall impact of crime in the community, we run our analysis at both the individual and aggregate levels to disentangle the opposing effects responsible for the disagreement in the literature. To our knowledge, we are the first to make such causal claims on defensive gun use, as well as the first to use a spatial (rather than temporal) identification strategy in the general guns and crime literature.

The key to our causal analysis is an instrumental variable approach based on the location of shooting ranges as a factor that exogenously increases the likelihood of defensive gun use in a community. We obtain incident-level data from the Gun Violence Archive, a compilation of more than 360,000 gun-related incidents such as homicides, robberies, burglaries, mass shootings, firearm suicides, or unintentional shootings from 2014-2023 across the United States, of which about 11,500 incidents over our ten-year data period involved self-defensive gun use. By combining media and government sources as well as local police reports, the GVA sample contains information about the exact location, severity, lethality, and type of gun crimes being committed. However, it is not a random sample of all DGUs, since more violent crimes are more likely to be reported to the police and covered by the media[2]. Moreover, since the dataset only includes gun-related incidents, it tends to overrepresent the most lethal crimes. Furthermore, because GVA does not indicate whether the suspect was armed, our dataset will include incidents where the victim is armed and the suspect may or may not be armed as well as situations where the victim is unarmed, in which case the suspect must be armed to be included in the data.[3] Ideally, we would like to compare cases of armed versus unarmed victims against the identical population of suspects but in our sample the unarmed victims are more vulnerable since they always faced armed suspects. This is potentially problematic because non-gun and gun crimes have very different outcomes (Cook, 2018). Based on Hemenway, Shawah and Lites (2022), however, about 48–70% of our defensive gun use incidents respond to an armed criminal.[4] Thus, our incident-level comparisons of DGU and non-DGU in-

[2]GVA defensive gun uses are always confirmed by police reports, not by news sources or victim narrative alone, so it is more reliable than surveys. However, cases where guns deter crime without being reported to the police are not captured in the dataset, which mostly reports cases where shots are fired by the defender (Hemenway, Shawah and Lites, 2022).

[3]While it is not systematically coded, it would be possible to obtain this information from reading the news article associated with each incident, as done in Hemenway, Shawah and Lites (2022) for a subsample. This is however not a trivial task for our full sample of 11,500 DGU incidents.

[4]Kena and Truman (2022) find instead that offenders have a firearm in only 28% of cases in NCVS data. This lower range is consistent with GVA recording only the more violent instances of crimes, such

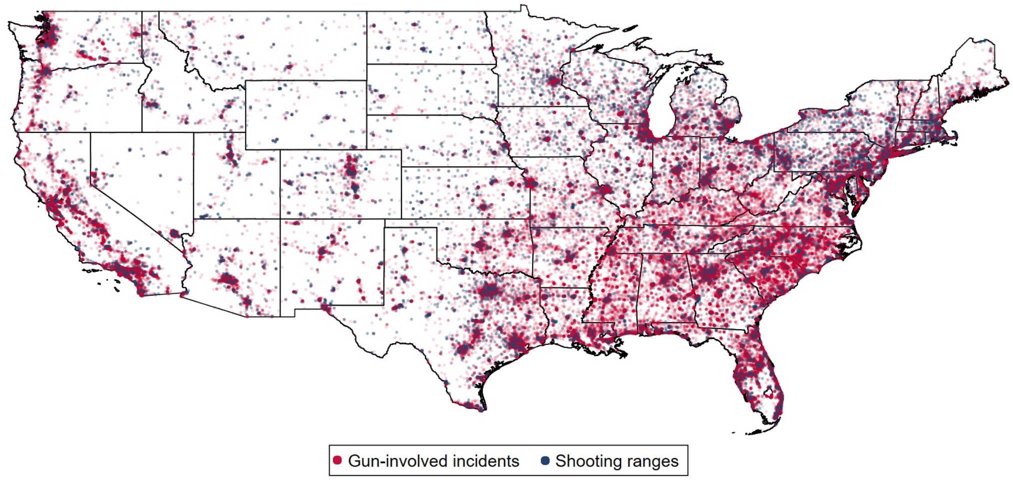

Figure 1. Gun incidents in the United States, 2014-2023

cidents will overestimate the protective power of DGU because of the substantial minority of defensive uses against an unarmed suspect. For these two reasons, our individual-level results are an upper bound of the efficacy of defensive gun use. However, our aggregate results should capture the general effect of more guns being openly carried, brandished, or shot, as long as the incidence of these passive forms of DGUs correlates strongly with the shots-fired, active DGUs we observe.

We obtain the locations of about 7,600 shooting ranges in the continental United States (as of 2023) by compiling the results of the "shooting range" query on Google Maps. Figure 1 shows that the spatial distributions of both GVA incidents and shooting ranges correspond to the urban centers of the United States. We then match incident locations to their nearest shooting range and argue that—conditional on some demographic and spatial controls[5]—people are more likely to own, carry, and use a gun near shooting ranges but crimes are not otherwise more likely to be more violent or lethal near them. The location of shooting ranges is thus a valid instrument to study the effect of defensive gun use on the severity of crime.

We run our regression at both the incident and county levels to capture the direct and indirect effects of defensive gun use. The incident level investigates whether defensive gun use may impact the probability of a victim or suspect

as when both the suspect and victim are armed.

[5]These include block-group-level or county-level density, rent, population age, race, income, home-ownership, political leaning, and firearm suicide rate, as well as state firearm ownership rates, state fixed effects, and year fixed effects, if applicable. We argue that these controls capture most of the factors that influence shooting range location as well as local crime, so that the exclusion and exogneneity conditions hold.

getting killed or injured in a given incident, regardless of whether the total number of crimes or their overall level of violence is impacted by guns. We thus first regress whether the victim or suspect got killed or injured on whether the victim defensively used a gun using the driving distance to the nearest shooting range as an instrument.[6] Given the binary nature of the outcome variable, we use a probit instrumental variable specification.

We then conduct a county level analysis that zooms out to estimate the total effect of increased defensive gun use on crime, capturing the potential unobserved deterrence effect as well as any change in the overall severity and number of crimes. We thus regress the number of gun incidents, violent crimes, deaths, and injuries per 100,000 people on the number of defensive gun uses per 100,000 people using the density of shooting ranges as an instrument, using a standard instrumental variable approach. Both regressions use spatial and demographic controls to account for shooting range location decision, making its exact location exogenous.

Our results suggest that defensive gun use, at least in the selected set of cases where the gun is actually fired, may function as intended for individual victims but that the widespread carry and use of guns increases crime in the aggregate, implying that the violence-facilitating, escalatory indirect effects of guns outweigh their indirect deterrence effects and protective direct effects. For a given incident in the selected GVA sample, DGU accompanies a significantly and sizably lower probability of death and injury for the victim, with a higher probability of death and injury for the suspect.[7] However, at the county level, we find that more DGUs are associated with significantly higher numbers of deaths and injuries for both victims and suspects, as well as a higher number of violent crimes. We additionally find that defensive gun uses are associated with more arrests for unlawful possession of guns, suggesting that gun theft might be an important mechanism behind this discrepancy. Our findings support the conclusion that the widespread carry and use of guns is detrimental to public safety, creating more opportunities for criminals to obtain guns—either legally or through theft—and that the deterrent power of DGU does not sufficiently counteract the spike in violence that originates from the prevalence of guns.

These results contribute to the broad crime literature in several ways. Most importantly, we contribute to public economics as we shed light on the impact of guns on crime, a topic which has been studied through various lenses and often provided conflicting results (see, e.g., Chalak et al. 2022; Donohue 2022; Tannenbaum 2020; McClellan and Tekin 2017; Cheng and Hoekstra 2013; Cook and Ludwig 2006; Levitt 2004; Ayres and Donohue 2002; Duggan 2001; Moody 2001; Dezhbakhsh and Rubin 1998; Ludwig 1998; Lott and Mustard 1997), by providing a new instrumental spatial approach to the question. Our results reinforce the

[6]Our results are qualitatively robust to using the straight-line distance instead (Online Appendix II).

[7]One important exception to this result is in road rage incidents, where guns are more likely to escalate the situation rather than to protect the victim. We correspondly find a higher likelihood of victim fatality in such incidents.

broad consensus that a higher number of privately-owned guns tend to increase the number of violent crimes rather than deterring them, possibly by facilitating gun theft, as suggested by Donohue et al. (2023) and Billings (2023), or by incentivizing conflict escalation and preemptive violence (O'Flaherty and Sethi, 2010). Beyond economics, we advance the efforts in public health and criminology to measure the efficacy of defensive gun use (see, e.g., Hemenway and Solnick 2015; Tark and Kleck 2004; Kleck and Gertz 1995) by providing what we believe to be the first causal estimates of this relationship, as these fields typically rely more on survey estimates than quasi-experimental data.[8]

The remainder of this paper is organized as follows. Section I presents the Gun Violence Archive dataset. In section II, we describe our instrumental variable approach and assumptions. Section III presents the individual incident-level results, and section IV the aggregate county-level results. Section V concludes.

I. Data on Defensive Gun Use

This paper uses the Gun Violence Archive (GVA) dataset, a nonprofit and independent data collection effort that samples gun-related incidents in the United States since 2014 (GVA, 2023). This dataset is more commonly used in the field of public health and is known to be one of the only accurate granular samples of both fatal and nonfatal firearm incidents (see, e.g., Doucette et al. 2022). In this section, we compare the GVA to other common firearm and defensive gun use datasets, namely the National Crime Victimization Survey (NCVS), the FBI's Supplementary Homicide Reports (SHR), the Center for Disease Control and Prevention's mortality reports (CDC WONDER), and DGU surveys such as English (2022).

Surveys on the frequency, circumstances, and efficacy of defensive gun use in nonfatal encounters vary widely: the Bureau of Justice Statistics' NCVS estimates between 50,000 and 100,000 incidents annually, while private surveys, admittedly severely criticized for their methodological shortcomings, find figures of 2 million or more. The NCVS figures, which are both more methodologically sound and consistent with other information about crime and responses to criminal attacks, are nationally representative and generously sampled, with nearly 227,000 interviews conducted in 2022. NCVS respondents are asked: "In the past six months, have you or has anyone in your household been a victim of a crime or attempted crime?" The idea that many individuals who used a gun in the last six months to thwart a criminal attack would fail to respond affirmatively to this question is highly implausible. All such individuals are then asked what they did in response to this crime or attempted crime, and since gun use to thwart crime is so positively regarded and often so highly lauded in the US, it is very unlikely that this

[8] Cook and Ludwig (1998) indeed point out that such "nationally-representative" surveys may suffer from biases generated by inaccurate retrospective reporting—to a degree that renders them unreliable for describing public safety conditions and/or making policy decisions.

question leads to an undercount of actual and legal defensive gun use. Hemenway has shown that if anything the miscount likely goes in the other direction where arguments that lead to illegal defensive gun use are inaccurately reported and then recorded as defensive gun use in response to threats of assault. Still, there may be cases in which a respondent unlawfully possessing a gun might be reluctant to admit to an ostensible government enumerator (despite the assurances of confidentiality) that the respondent wielded a gun defensively, but again these are not likely to be highly beneficial gun uses. In contrast, surveys of 5000 gun owners by Kleck and Gertz (1995) and 15,000 gun owners by English (2022) have generated staggering counts of defensive incidents that are difficult to reconcile with the actual volume of firearm injuries admitted to hospitals. Indeed, these surveys have been shown to be marred by such serious methodological problems leading to wholly implausible overcounts (such as the claim referenced above that there are perhaps 400,000 incidents per year in which the defensive gun uses saved lives) that they are probably not worth serious consideration. (See Hemenway, 1996 and Hemenway and Solnick, 2015.)

Because these surveys rely on survivor narratives, to our knowledge GVA is the first source to record defensive gun use by homicide victims. Until 2020, reports by the FBI's SHR provided more detail on fatal encounters, including how many involved a firearm, tabulated under their Uniform Crime Reporting (UCR) program. The CDC's mortality statistics offer the most comprehensive count of homicides committed with a firearm, which we use to evaluate the completeness of the GVA and SHR homicide data universes. We expect GVA's coverage to be best for the most egregious offenses, and it is: each year, GVA captures more fatalities than SHR albeit somewhat less than the core UCR and CDC murder counts, as seen in Table 1.

Most crucially, unlike GVA, neither NCVS nor private surveys collect incident-level attributes. Furthermore, GVA combines police and media reports to verify the occurrence and nature of each entry, avoiding the subjectivity, retrospection, and exclusion of homicide circumstances innate to survey methods. Other sources with similar goals are far less comprehensive: as the Gun Violence Archive includes more than 11,500 records of defensive gun use since 2014 (out of about 360,000 total gun-involved incidents), the Heritage Foundation's database contains only 3,600 defensive gun use instances dating back to 2019.

Table 1 compares GVA adversarial situations between private citizens—dropping the roughly 8% of incidents classified as suicides and officer-involved shootings—with estimates from NCVS[9] and the National Firearms Survey (English, 2022). The NCVS figures report the total number of defensive gun uses: the sum of the DGUs against personal violent crimes (rape or sexual assault, robbery, and aggravated assault) and DGUs against property crimes (burglary or trespassing,

[9]From 2019 onward, yearly NCVS reports no longer estimate total incidents but only victim counts; calculating the victims per incident figures for the years 2014-2018, we find that the vast majority of violent crimes target a single victim anyway.

motor vehicle theft, and other types of theft). While the GVA data offers unparalleled geographical granularity, it still undercounts crime and defensive gun use because of the exclusion of minor interactions and unreported offenses. These data limitations should not be problematic as we attempt to identify the impact of defensive gun use as long as our instrumental variables approach is valid.

To be included in the GVA data, an incident must involve an attacker with a gun, defensive gun use, or both. Because in cases of defensive gun use, the GVA data does not uniformly report if the perpetrator is armed, we end up with a skewed data set that tends to exaggerate the effectiveness of defensive gun use. This bias arises because the GVA dataset compares defensive gun use incidents where the suspect may or may not be armed to non-defensive incidents where the suspect is surely armed. By reading the details of over a quarter of the defensive gun use entries from 2019, Hemenway, Shawah and Lites (2022) found that the perpetrator was reported to be armed with a firearm in 48% of cases and with uncertainty in another 22% of the incidents. Again, this fits the tendency of the GVA to include only the highest-stakes gun incidents, those that are most likely to be reported to police and picked up in media coverage; the aforementioned 5-year NCVS report estimates that the offender had a firearm in only 28% of the violent-crime defensive gun use cases. Thus, defensive and non-defensive encounters are comparable in about two-thirds of our defensive gun use incidents, since the attacker is armed in every single non-defensive incident that makes it into the GVA but in only 48–70% of the instances of defensive gun use. This prevents us from placing too much weight on the exact magnitude of our estimates, but they do serve as a generous upper bound of the protective power of defensive gun use. As for perpetrator deaths due to defensive gun use, Hemenway, Shawah and Lites (2022) estimate 559 perpetrators killed in self-defense in 2019. This is consistent with UCR's figure of 334 justifiable firearm homicides by private citizens, considering that in some GVA homicides—labeled as "drug-related incidents," "gang activity," or escalating arguments—the victim-suspect classification might not be clear-cut enough to be considered justifiable.

As of 2019, the Gun Violence Archive draws upon "up to" 7,500 sources which are a mix of public information from law enforcement, government and media sources; the majority of sources were added in 2015. Although GVA claims to be unbiased and retains a dedicated professional staff to log incidents, there are still some known issues with the randomness of the data. Previous work found that only 50% of incidents of firearm assault found in police department records ultimately appear in the media reports leveraged by GVA, based on a limited subsample of three cities in 2017 (Kaufman et al., 2020). Further, the coverage of these incidents, and thus GVA's access to them, is nonrandom. In particular, media reporting varies by city, fatality, number of victims, and victim gender at the 1 percent significance level; while there is no significant difference in reporting across race, victim age is also significant at the 10 percent level. Despite these biases in the GVA's composition, we still find it reasonable for our purposes

Table 1—Characteristics of the GVA against common firearms databases

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023 (Jan-Aug)
Gun Violence Archive (GVA)										
Total adversarial firearm incidents	23,854	29,068	33,291	34,116	31,064	32,920	43,245	44,885	42,671	25,554
% of NCVS police-reported	7.0	14.6	12.4	14.6	11.0	—	—	—	—	—
Total victims injured	19,772	24,198	27,748	28,242	25,395	27,553	36,707	37,720	35,742	21,944
% of NCVS police-reported	5.2	11.1	8.8	11.1	8.2	9.5	17.3	15.9	9.2	—
Total victims killed	8,848	10,055	11,483	11,852	10,988	11,662	15,918	17,039	16,101	9,326
% of CDC	80.4	77.5	79.7	81.5	78.7	80.9	82.1	81.3	82.0	—
Total suspects killed	327	436	537	595	562	576	604	636	591	349
% of CDC	3.0	3.4	3.7	4.1	4.0	4.0	3.1	3.0	3.0	—
Total defensive gun uses	722	932	1,313	1,448	1,271	1,165	1,190	1,167	1,139	693
% of NCVS shots fired	3.9	7.4	4.8	19.2	9.0	7.1	10.8	10.6	5.0	—
With shots fired (Hemenway)	—	—	—	—	—	1,064	—	—	—	—
National Crime Victimization Survey (NCVS)										
Total firearm incidents	414,700	260,200	414,440	417,780	427,730	—	—	—	—	—
Total firearm victimizations	466,110	284,910	486,590	456,270	470,840	481,950	350,460	326,890	640,710	—
% reported to police	81.9	76.5	64.6	55.9	65.9	60.3	60.6	72.8	60.8	—
Victims per incident	1.12	1.09	1.17	1.09	1.10	—	—	—	—	—
Total defensive gun uses	58,394	56,161	96,514	58,655	96,686	53,347	69,099	70,605	55,803	—
With shots fired	18,412	12,591	27,255	7,526	14,197	16,477	10,990	10,998	22,793	—
English (2022)										
Total annual defensive uses						1.67–2.8 million				
With shots fired						302,270				
FBI Supplementary Homicide Reports (SHR)										
Total homicides (UCR)	14,164	15,883	17,413	17,294	16,374	16,669	21,570	—	—	—
Total homicides (SHR)	12,281	13,783	15,320	15,312	14,605	14,678	18,965	—	—	—
of which, firearm homicides	7,806	9,104	10,378	11,097	10,557	10,725	14,501	—	—	—
of which, justifiable	277	268	278	313	317	334	—	—	—	
CDC Mortality Statistics										
Total firearm homicides	11,008	12,979	14,415	14,542	13,958	14,414	19,384	20,958	19,642	—

Source: GVA (2023), Hemenway, Shawah and Lites (2022), CDC (2023), NCVS (2022), FBI (2023), English (2022).

Table 2—GVA defensive gun use in the United States, 2014-2023

	All incidents	Inside of home	Outside of home
Defensive gun use incidents (DGU)	11,587	3,443	8,144
of which:			
victim(s) were injured	3,090 (26.7%)	658 (19.1%)	2,432 (29.9%)
victim(s) were killed	1,273 (11.0%)	216 (6.3%)	1,057 (13.0%)
suspect(s) were injured	5,055 (43.6%)	1,706 (49.5%)	3,349 (41.1%)
suspect(s) were killed	4,544 (39.2%)	1,490 (43.3%)	3,054 (37.5%)
suspect(s) were arrested	3,419 (29.5%)	1,094 (31.8%)	2,325 (28.5%)
Total number of victims injured	3,911	754	3,157
Total number of victims killed	1,439	241	1,198
Total number of suspects injured	5,400	1,839	3,561
Total number of suspects killed	4,677	1,555	3,122
Total number of suspects arrested	4,709	1,674	3,035

Note: The share of each sub-incident with respect to all DGU in the category is reported in parenthesis.
Source: GVA (2023)

as long as reporting within cities remains consistent over time after the influx of sources in 2015. Systematic evolution in selective coverage seems unlikely, given the relative invariance of incentives for newspapers, governments, and law enforcement. Specific to our context, we do not expect to see differential coverage of incidents as a function of distance to a shooting range or density of shooting ranges. Thus, the biases and underreporting of the GVA data should not impact our qualitative results.

Table 2 details the outcomes of all defensive gun uses in the GVA dataset, first in terms of number of incidents and second in terms of number of death/injuries. Since a single incident may yield multiple casualties, the second figures are higher than the first. In our 11,587 defensive gun use cases, 5,400 suspects were wounded and 4,677 were killed over the ten-year data period; in those same incidents, 3,090 victims were wounded and 1,273 were killed. The DGU incidents recorded by GVA thus tend to be highly lethal for both the victims and the suspects. Defensive gun uses during home invasions tend to be more lethal for the suspects and less lethal for the victims than DGUs happening outside of the home, with a staggering 43.3% of home DGU leading to the death of suspects compared to 37.5% of non-home DGU, and only 6.3% of home DGU leading to the death of victims compared to 13.0% of non-home DGU. Once again, it is important to note that GVA records only the most violent and active instances of defensive gun uses, explaining such a high proportion of injuries and deaths in our dataset.

Overall, while we recognize its limitations, the Gun Violence Archive remains the only source of granular defensive gun use data available. Most importantly, it is the only dataset that allows for the spatial identification methods used in this study. Nonetheless, our incident-level results are ultimately based on a sample of the most violent and active DGUs, with shots fired in most cases (Hemenway, Shawah and Lites, 2022), so we necessarily overestimate the protective power of guns. Our aggregate results, on the other hand, should more closely reflect the potential deterrent power of defensive gun use including passive instances of DGU, such as the visual threat of open carry, verbal warnings about being armed, or the drawing of a gun without shots being fired. This is because we expect proximity to a shooting range to affect violent and passive defensive gun use similarly (after controlling for demographics and spatial characteristics), such that the violent incidents in GVA accurately proxy the total number of defensive gun uses.

II. Instrumental Variable Approach

To discern the causal effect of defensive gun use on crime, we use two measures of proximity to a shooting range as instruments for the probability that a victim is armed and thus has the ability to use a gun defensively. In our incident-level regression, the driving distance to the nearest shooting range instruments for the likelihood of defensive gun use in a given victimization, with likelihood of injury (or mortality) as the dependent variable. At the aggregate level, the ratio of shooting ranges to county population instruments for the rate of defensive gun use per 100,000, with injuries (or deaths) per 100,000 as the dependent variable.

The observable bidirectional relationship between defensive gun use and incident outcomes contains two types of endogeneity. First, the unobserved circumstances of a given incident—perceptions of power, emotional stakes, mental states—drive both the decision to use a gun defensively and the injury/mortality risk of both the victim and suspect. Even after conditioning on the type of situation (armed robbery, home invasion, or bar fight), defensive gun use conditional upon being armed is the result of a conscious optimization—and thus would be expected to lead to more favorable outcomes for the victim than had it been random. This endogeneity is fundamental: even if we could observe the outcomes of two crimes, identical except that the victim chooses to use a gun in one and not the other, it would be impossible to isolate the effect of the gun from the composite effect of the factors that led to its use. Further, we are interested in estimating the effect of DGU on a given crime only when it is rational, so this type of endogeneity does not bias our estimate. Instead, we are more concerned that the majority of victims in cases of defensive gun use carry far more often than the typical crime victim and wield far more effectively. That is, given a particular defensive gun use instance, the person holding the gun might be fundamentally far more competent than the typical victim. Conditional on a certain crime being committed, a veteran, off-duty security guard, or gun enthusiast, might be expected to de-escalate better, draw quicker, or shoot truer (depending on what the situation demands) than the average potential victim in GVA. On the other hand, their greater willingness to use their gun might escalate the situation, decreasing their likelihood of escaping unscathed. It is thus unclear *a priori* whether proximity to a shooting range overall decreases or increases the incident's lethality, but a difference can be expected. In our empirical model, we make no formal assumption about why or in which direction they might differ, only that habitual gun wielders might have a different probability of injury or death than the average person, such that a standard regression would fail to capture the desired causal effect.

Our instrument, proximity to a shooting range, induces more citizens to carry guns when they otherwise wouldn't. People who carry and use guns defensively, regardless of distance to the range, are always-takers, while those who tend to carry more while they are close to a range are considered "induced" by the instrument, or compliers. We do not, however, imagine that proximity to a range impacts the average firearm user's level of training beyond providing the minimum requisite handling familiarity that facilitates carrying. Put another way, proximity to a range correlates with proficiency in casual sport shooting, which does not in turn affect proficiency in using a gun defensively, as the vast majority of skills are not transferable between the two contexts (accuracy over distance in a safe, controlled environment vs. reacting at close-range under time pressure and making snap judgments). Then, in capturing the degree to which people are induced, we identify the effect of DGU on crime, were the average GVA victim to decide that performing DGU is in their best interest.

The same concerns are present at the aggregate level. That is, geographical areas may see a higher number of DGUs because residents are responding to a higher number of crimes or generally feeling unsafe. As such, a positive correlation between the number of defensive gun uses and, for instance, the number of victims killed does not imply that defensive gun uses are increasing the number of homicides. We thus use the density of shooting ranges to instrument for the number of defensive gun uses and solve this reverse causality issue. Controlling for gun ownership, we are able to use the rate of defensive gun use as a proxy for the overall crime-deterrent or criminogenic effect of people carrying and using their guns; mechanically, more defensive gun uses occur when more people carry guns. Therefore, instead of representing the direct effect of an increase of one defensive gun use per 100,000 population on victimization outcomes, our aggregate regression coefficients capture the causal equilibrium effect of an increase in the propensity of gun owners to carry their guns on county crime dynamics. We additionally study how this mechanism impacts the number of arrests for unlawful possession, to assess whether more guns carried are associated with more guns being stolen and used by criminals.

We capture the locations of most public and semi-private shooting ranges in the continental United States by compiling the results of the "shooting range" query on Google Maps. There is no centralized listing or official count of shooting ranges in the United States, most likely due to the few restrictions on opening them: operators do not need special licenses as long as they do not sell or rent firearms. Since we are only interested in shooting ranges that are accessible to the public, the Google query is likely to capture the vast majority of businesses of interest. We obtain the location and operation status of 7,678 shooting ranges as of September 2023, including indoor and outdoor shooting ranges, ranges attached to a gun shop, gun clubs, and shooting clubs in general. This approach does not appear to significantly pick up gun clubs or shops that do not have shooting ranges.[10] Further, even if we do pick up on non-range businesses we have no reason to believe that there would be any systematic differences between geographic regions, so we would not expect misestimation to be systematic.

The remainder of this section argues that the proximity to a shooting range serves as a valid instrument, conditional on neighborhood demographics: density, rent, population age, race, income, house ownership, political leaning, firearm suicide rate, state firearm ownership, state, and time. We describe the exact instrumental variable specifications for our individual and aggregate regressions in sections III and IV, respectively.

A. Relevance Condition

The relevance condition is different enough in the individual and county regressions to warrant separate discussions. We begin with the explanation for individual, as it provides useful intuition for relevance at the county level.

At the individual level, we instrument for the probability of defensive gun use in a given incident by using the driving distance to the nearest shooting range. Thus, our relevance condition is that crimes happening closer to a shooting range are more likely to be met with a DGU response. The intuition is simply that more people carry guns closer to shooting ranges. As we control for gun ownership rates, this assumption is not simply a matter of there being more guns near ranges, but rather that people may be more likely to carry their guns near ranges. Not only is it that they might be on their way to and from the shooting range, thus carrying their weapon, but also that people residing near a shooting range are more likely to train and get comfortable with a gun, making them more likely to carry it in their daily lives. Thus, even when controlling for the sheer number of guns in an area, the distance to a shooting range can still be reasonably expected to impact the probability of defensive gun use through its effect on the likelihood

[10] One could imagine for instance that a gun shop with multiple user reviews stating that they do *not* have a shooting range could get picked up by Google when querying for "shooting range." We manually checked the websites of about 40 of our results in Northern California and found only 2 instances of gun shops not having a shooting range and yet appearing in the "shooting range" query. We argue that these rare false positives are not significant enough to be a concern or be systematically different between states, and that the Google query algorithm is developed enough to accurately pick up places that include a shooting range in most instances.

of an individual carrying a gun and thus have the option to DGU if they are victimized.

At the aggregate level, we instrument for the overall rate of defensive gun use by using the density of shooting ranges in the area. Our instrument will be valid if the density of shooting ranges in a county gun carrying in the same county, conditional on covariates, but does not affect our dependent variables of interest except by increasing gun carrying. Again, we note that we include proxies for gun ownership in our vector of controls, cutting out that channel as a possibility. Rather, the channel through which the density of shooting ranges instruments for the number of defensive gun use is by increasing the average propensity to carry a gun. The same argument as above applies here, thus, through the channel of more people carrying guns, there will mechanically be more chances to defensively use them and thus more defensive gun use. We also note that the ethnographic, sociological, and qualitative literature describes a substantial overlap between sport shooters and those who own guns for defense. Kohn (2004) studies a tripartite sample of Northern Californian hobbyists who share an interest in self-defense despite their political and demographic diversity. Boine, Caffrey and Siegel (2022) use latent class analysis to decompose American gun owners into six subcultures. About three-quarters of those categorized as "family protectors" or "self-protectors" report visiting the shooting range regularly, comparable to the 81% of "target shooters" who report doing so. The "Second Amendment activists," another significant group, also list defense of self or others as a primary objective nearly half the time; 93% visit the shooting range regularly.

In both instances the theoretical reasoning holds up empirically. We find a robust F-statistic of 10.60 at the county level, comparing the density of shooting ranges in counties to their defensive gun use rates, which is enough not to be concerned with a weak instrument issue and allows for valid two-stage least squares estimation (2SLS) as shown in Stock, Wright and Yogo (2002). At the incident level, we use a non-linear estimation based on a bivariate probit model, for which there does not exist an equivalent to the F-statistic and where weak instruments are a lesser problem. We instead test the bivariate distribution assumption of our instrument and show that our results are robust to various copulas. Both tests are explained in more details in their respective empirical sections.

B. Exclusion Condition

For the exclusion restriction to hold, proximity to a shooting range should not impact victim or suspect outcomes on the incident level, or crime composition on the aggregate level, other than through increasing the likelihood that people are carrying guns—and ultimately using them defensively. We begin with the slightly more straightforward intuition of the aggregate context: an increase in the density of shooting ranges in a county does not impact the number of gun-related criminal incidents, other than through the law-abiding residents' increased propensity to carry guns, which affects the final number of observed defensive gun uses. Clearly, incidents on the extensive margin, those that would not be in GVA were it not for the occurrence of DGU (e.g. involving an unarmed suspect or an altercation that would not have escalated without a gun), mechanically increase the number of gun-related incidents we observe, but only through the channel of defensive gun use. Increasing DGU incidents on the intensive margin—where the perpetrator is armed, so the incident is already violent and gun-involved regardless of whether DGU is performed—does not change the total number of GVA observations. Neither case violates the exclusion restriction. Instead, exclusion may be indirectly threatened by the fact that violent-crime patterns as well as rates of defensive gun use reflect local levels of gun ownership and gun culture. We attempt to break this link by including a commonly-used proxy for gun ownership (the ratio of firearm suicides to total suicides) at the county level, as well as RAND's estimates of household firearm ownership at the state level. In doing so, we avoid observing mechanical increases in gun crimes due to increases in guns owned. Further, we do not expect that increasing either the number of guns carried or average firearm training will have an appreciable direct effect on the lethality of gun crime, outside of those two mechanisms' effect on DGU.

Analogous logic applies to our incident-level regression, where we estimate the outcome variable by a probit transformation of the ratio of likelihood of injury or death to the number of incidents. Again, non-DGU incidents in GVA must include the use of a gun by the suspect (intensive margin), while DGU incidents potentially include non-gun crimes which would not make it into the data had the DGU not occurred. These non-gun crimes with defensive responses "induced" by increased carrying near a shooting range do not create an issue as they are only included in the data on the extensive margin, through the channel of more carrying encouraging defensive gun use. Thus, both at an individual and county level, we expect the exclusion condition to hold.

C. *Exogeneity Condition*

Conditional on covariates, we assume that the density of gun ranges in a county is as good as random. Commercial market reports such as those prepared by the National Shooting Sports Foundation (NSSF, 2020) may give us some insight into the location decision process of prospective shooting range operators. Such reports assess factors specific to the neighborhood within a 10- or 20-mile radius of their potential location as well as indicators of statewide interest. First, the local demographics included in the report—age, race, marital status, household type and size, income, education, employment, and so on—all appear to be drawn from the American Community Survey, where we too derive our block-group-level and county-level controls. Effective buying income, which factors heavily into the reports, is highly collinear with median household income and gross rent, which we already include. From the demand perspective, surveys such as the NORC, BRFSS, and GSS find that legal gun owners tend to be older, more male, richer, and whiter than the average American, while living in more rural areas, particularly in the Midwest and the South (Hepburn et al., 2007). The report further includes several lists of increasingly general nearby business types: other shooting ranges, "related businesses (gun dealer, preserve, range, retailer, etc.)," law enforcement and law enforcement supplies retailers, and federal firearm license holders, an umbrella category that includes all businesses approved to handle the manufacture, import, or sale of firearms. Second, the report calls attention to the state-level volume of background checks performed by the National Instant Criminal Background Check System and the National Sporting Goods Association's annual estimates of participation in several shooting sports. Including state-year fixed effects in our model completely captures any variation in these attributes, as well as in state-level gun policies. Finally, we find no evidence that local crime patterns exert a direct effect on range location or operation (at least, no more than the average storefront). The sample report includes a page of burglary-prevention tips, mostly suggestions to install cameras, alarms, and gun safes. Relocation is not mentioned; in fact, security seems to take a backseat compared to the aforementioned profit-driving factors under consideration.

Finally, to match the NSSF's proxy for number of potential clients—estimates of sport shooters in the neighborhood of the would-be gun range—we control for county and state firearm ownership rates. First, lacking reliable information on legal—let alone illegal—firearm access, researchers have long used the ratio of firearm suicides to all suicides as a proxy for gun prevalence[11]. Using the CDC mortality data, we compute this ratio at the county level. Second, the RAND Corporation uses structural equation modeling to produce state-level estimates of household firearm ownership, using 51 surveys, numbers of hunting licenses, subscriptions to *Guns & Ammo* magazine, background checks, and the suicide ratio itself. By drawing upon more sources of information and larger population bases, these numbers are less prone to undue fluctuation driven by small changes in suicide counts, but they also necessarily fail to capture the local dynamics that most interest us. Conditioning upon both measures of ownership helps ensure the exogeneity of range location, as it is hard to think of a more overt indicator of demand for sport shooting.

As the NSSF charges prospective range owners up to $2,500 for these reports, they presumably contain the best available parameters to measure both local demand and existing competition. In our aggregate analyses, we believe we comprehensively cover factors that influence county-level crime and gun activity, while the exogeneity of our incident-level instrument is further bolstered by the block-group resolution at which we obtain our controls: while the NSSF reports pertain to areas of at least 300 square miles (within a 10-mile radius of the potential range), and often rely on characteristics over much larger areas (the state), the United States is partitioned into over 217,000 census block groups, generally containing 600 to 3,000 people and spanning only a few square miles each. Thus, it seems highly unlikely that a prospective shooting range operator would be able

[11]See Donohue (2022) for a more complete discussion of papers using the firearm suicide ratio.

Table 3—Geographical determinants of gun incidents and shooting ranges

	Shooting ranges	Gun-related incidents	Defensive gun use
Density	-0.129	-12.447***	-0.440***
	(0.198)	(1.817)	(0.136)
Rent	-0.012***	-0.351***	-0.008**
	(0.002)	(0.077)	(0.003)
% Male	0.089***	1.183***	0.046***
	(0.010)	(0.247)	(0.012)
% 18-25 years old	0.002	-1.125***	-0.008
	(0.008)	(0.202)	(0.008)
% 35-55 years old	0.006	-0.644**	0.012
	(0.007)	(0.248)	(0.011)
% White	0.012***	-0.521**	-0.012
	(0.003)	(0.236)	(0.007)
% Black	-0.007	8.409***	0.138***
	(0.004)	(1.111)	(0.018)
% Hispanic	-0.013***	1.157***	0.020
	(0.004)	(0.293)	(0.015)
% Homeowner	0.022***	-1.122***	-0.028***
	(0.007)	(0.221)	(0.006)
Median household income	0.024	-7.553***	-0.160***
	(0.027)	(1.642)	(0.039)
State firearm ownership	1.304***	6.609	-0.544***
	(0.009)	(4.072)	(0.068)
County firearm suicide	0.034***	0.722	0.048**
	(0.011)	(0.926)	(0.020)
County republican vote	0.054***	-3.048***	-0.081***
	(0.009)	(0.644)	(0.019)
State fixed effects	Yes	Yes	Yes
Number of block groups	159,845	159,845	159,845
R^2	0.014	0.279	0.042

Note: OLS regressions of the number of shooting ranges, incidents, and defensive gun uses in a block group on various block group characteristics. All variables are at the block group level unless otherwise specified. Rent is in thousands; density and household income are in millions. Data and sources are described in the text. Standard errors in parenthesis and clustered at the state level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

to discern, much less act upon, demand for recreational shooting on anything approaching the block group level, given the limitations imposed by land availability and zoning ordinances. Additionally, because of ranges' low turnover and relative longevity, we do not expect meaningful survivorship bias to arise, since less than 2% of the 7,600 total scraped shooting ranges were identified by Google as temporarily or permanently closed.

Table 3 shows how our controls are correlated with the location of shooting ranges and gun incidents through standard regressions. Consistent with the aforementioned demographic profiles of gun owners and hobbyists as well as the factors that go into the decision to open a range, shooting ranges tend to be located in older, whiter, male-dominated census block groups with relatively higher rates of homeownership but lower population density and household income (i.e. low median rent). Gun-related incidents and defensive gun uses tend to be located in black, poorer, and older[12] block groups. As evidenced by the low R^2, substantial randomness in shooting range location remains, further validating our exogeneity condition.

Our final dataset covers adversarial situations between private citizens (excluding suicides and officer-involved shootings) occurring in the continental United States[13] over the January 2014 to August 2023 period, resulting in 332,053 gun-related incidents including 10,901 instances of defensive gun use from GVA (2023). Shooting ranges are as of September 2023 and collected by the authors. Demographic controls are 2014-2018 averages from the US Census Bureau (2018). State firearm ownership rates are estimated by the RAND Corporation (Schell et al., 2020). Republican vote is the percentage of votes for Donald Trump in 2016 from the MIT Election Data and Science Lab (2020). The county firearm suicide rate is the ratio of firearm suicides over all suicides, averaged over the 2014-2023 period and taken from the CDC (2023) dataset.

III. The Incident-Level Effect of Defensive Gun Use on Crime Outcomes

We first study the effect of defensive gun use on the incident level. That is, once a crime is in motion, how does the victim pulling a gun affect their risk of injury or death? It is a complicated theoretical question about how would answer this question if one had perfect data and could implement a perfect randomized experiment. One might begin by thinking of randomly supplying individuals with guns that they could use for self-defense if attacked, but this is a slightly different test for two reasons: (i) many times that individuals were attacked, they would fail to have their gun with them or would not be able to use it for a variety of reasons, and (ii) those who were randomly assigned a gun might be emboldened to expose themselves to greater risk of criminal victimization when they were carrying the weapon. A second thought experiment that is closer to what we hope to shed light on would be to have everyone carrying a weapon, but that at the exact moment of attack, the armed victim would be randomly instructed that his weapon could not be used in any manner. This randomized experiment would

[12]This result might seem counterintuitive given the long-standing observation that peak crime age is in young adults (Farrington, 1986). Running a regression with only age covariates and no other variables reverses the negative coefficient on age 18-25 and makes it positive, which thus becomes consistent with Farrington (1986). We thus interpret the negative coefficient on age 18-25 to be due to the effect of young criminals being washed out by other variables such as race and income, as well as gun incidents happening where the victim—who is typically older as per Farrington (1986)—lives rather than where the perpetrator lives.

[13]We exclude Hawaii and Alaska from our spatial regressions due to their geographical specificities and complexity associated with driving distances between islands or sparsely populated areas. These represent less than 0.4% of the full GVA sample described in table 1.

tell us how a gun could influence that outcome of a criminal victimization, which is what we are trying to ascertain.

Of course, our examination falls short of this theoretically perfect experiment in two ways. First, we do not observe every potential victimization, but rather observe only those that both involve a gun used by either the criminal or the victim (or both) and generate enough publicity to make it into the GVA. Moreover, as noted previously, our data set will have cases where a gunowner victim confronts an unarmed attacker but never will have cases where an unarmed victim confronts an unarmed attacker. This data omission necessarily will make defensive gun use appear less risky and more effective than it is because in all of our cases without defensive gun use the attacker is armed with a gun.[14]

Second, we do not randomize who is in a position to use a weapon. A homeowner who can access a gun when he hears an unarmed 15-year-old trying to climb in a basement window can take aim from a very advantaged position, while a homeowner who wakes up with a suspect holding a gun at his head will have no opportunity to use a gun and will obviously be in a very disadvantaged position. Since we regress whether any victim or suspect was killed or injured in an incident on whether any victim defensively used a gun, our incident-level regression will attribute the more benign outcome of the first case to the presence of the homeowner's gun, even though the outcome in either case would likely be similar regardless of whether the first homeowner did not have a gun or whether the second owner did have one.

An instrument that exogenously makes defensive gun use more likely will at least allow us to explore whether the estimated incident-level effect of defensive gun use becomes more or less favorable through instrumentation. We use the driving distance to the nearest shooting range as an instrument for defensive gun use. As discussed in section II, we control for various demographic and geographic characteristics to make the instrument exogenous.

Following Wooldridge (2010), the standard instrumental variable regression must be substantially adapted to suit the bivariate nature of our variables. More specifically, both the outcome variable (getting injured or killed) and endogenous variable (occurrence of DGU) can only take the values 0 or 1, and we wish to infer probabilities from our coefficients. We thus use a probit instrumental variable approach and study its marginal effects to extract interpretable probabilities of getting injured or killed conditional on a gun being used or not. As pointed out by Han and Vytlacil (2017) and Han and Lee (2019), the binary nature of our endogenous variable additionally calls for a bivariate probit model, which we implement with the endogenous recursive bivariate probit of Coban (2021).

[14]Note that this problem should be mitigated to some degree when we narrow our focus to armed robbery case, since all of those cases should involve a suspect who has at least some weapon, but as the literature has long recognized, armed robbery where the suspect carries only a knife is far less dangerous to victims than armed robbery with a firearm.

Our two-stage probit specification is thus

$$\text{(1)} \qquad \mathrm{y}_i^* = \alpha + \beta \mathrm{DGU}_i + \mathbf{X}_i'\mathbf{\Gamma} + \sum_{s=1}^{S-1} \mathbb{1}_{i\in s}\alpha_s + \sum_{t=2014}^{2022} \mathbb{1}_{i\in t}\alpha_t + \varepsilon_i \,,$$

$$\text{(2)} \qquad \mathrm{DGU}_i = \mu + \delta \Delta \mathrm{SR}_i + \mathbf{X}_i'\mathbf{\Pi} + \sum_{s=1}^{S-1} \mathbb{1}_{i\in s}\mu_s + \sum_{t=2014}^{2022} \mathbb{1}_{i\in t}\mu_t + \nu_i \,,$$

where y_i^* denotes the variable of interest (the probability that the victim/suspect gets killed/injured) for a given gun-related incident $i = \{1, ..., N\}$, DGU_i indicates whether any victim of the incidents used a gun in self-defense, $\mathbf{X}_i$ is a 13×1 vector of controls (state firearm ownership rate, county Republican vote in 2016 and firearm suicide rate, as well as block group density, average rent, median household income, and the share of population that is male, aged 18-25, aged 35-55, White, Black, Hispanic, or homeowning), and $\Delta \mathrm{SR}_i$ is the driving distance to the nearest shooting range. We include state fixed effects α_s, μ_s for states $s = \{1, ..., S\}$ and year fixed effects α_t, μ_t for years $t = \{2014, ..., 2023\}$, removing one state and one year to avoid collinearity. We cluster our standard errors by state since incident outcomes within states are likely to be correlated via state-level gun legislation. We do not observe y_i^*, but only the binary outcome of the crime y_i based on whether any suspect or victim got killed or injured.[15]

$$\mathrm{y}_i = \begin{cases} 1 & \mathrm{y}_i^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

We take out the marginal effect of defensive gun use by computing its average treatment effect (ATE) and average treatment effect on the treated (ATET).[16] In this case, the treatment refers to the defensive use of a gun, and the ATE gives the theoretical increase or decrease in the probability of death or injury for any incident in the sample, regardless of whether a gun was actually used. In contrast, the ATET computes the same change in probability only across the instances where a gun was used by the victim. As long as the incidents with and without defensive gun use do not vary systematically in their covariates or by unobserved distribution over incident outcomes, the ATE and ATET should be roughly equal. These two approaches indeed yield broadly similar coefficients, yielding further confidence that we are capturing the effect of DGU on the average GVA victim.[17]

The endogenous recursive bivariate probit relies on a different set of assump-

[15] The two outcomes are not mutually exclusive: a robbery that kills two people and injures another will be categorized as both an injury and a fatality in the binary variable.

[16] See Coban (2021) for the formulation of the ATE and ATET.

[17] See Wooldridge (2010) and Hasebe (2013) for the full derivation of marginal effects and standard errors in this setting.

tions due to its non-linearities and maximum likelihood implementation, especially so for the first stage. There currently does not exist an equivalent to the F-test for nonlinear two-equations systems. We nevertheless report the linear F-statistic in Table 5 for completeness, which cannot rule out a weak instrument. However, weak instruments are much less of a problem in nonlinear two-equations systems[18], and a more important identification assumption is instead that the system is not identified due to a nonlinearity (Wooldridge, 2010); in fact, Chiburis, Das and Lokshin (2012) find that bivariate probit estimators are especially efficient relative to linear IV approaches when the treatment probability is close to 0 or 1. This is true of our data, where there are about 1,000 defensive gun uses annually, compared to around 30,000 gun-involved adversarial incidents. In contrast to the linear setting, our identification rests instead on the assumption that the dependence structure between the outcome (whether a victim or suspect is killed or injured) and the treatment (whether defensive gun use occurred) follows a bivariate normal distribution. We thus follow Winkelmann (2012) and Trivedi, Zimmer et al. (2007) and test various alternative distributional assumptions in Online Appendix I. Given that these alternative ATE's are stable across assumptions, our system is well-identified.

In our setting, the nature of the confrontation fundamentally dictates the interpretation of its outcomes. The victim calculus that drives the decision to DGU and the expected outcome of the DGU will be very different in an armed robbery versus a home invasion. Because of this lack of comparability, we separate our observations by crime type. Furthermore, some crimes systematically have better-defined victim(s) and suspect(s) than others. For example, in home invasions the victim is the homeowner, whereas in a bar or club fight the roles are less obvious.[19]

Table 4 decomposes the number of deaths and injuries per incident based on whether a victim used a gun defensively. It is immediate from these results that DGU incidents seem to be more lethal for the suspects but less lethal for the victims. For instance, an armed robbery yields an average of 0.11 victims killed in case of DGU compared to 0.34 in a non-DGU robbery. At the same time, the same armed robbery results in an average of 0.40 suspects killed in a DGU case compared to 0.02 in a non-DGU. Studying injuries instead of death, as well as other types of incidents (home invasions, road rage cases, and bar/club assaults),

[18]Indeed, in the linear case, weak instruments are an issue because a small first-stage parameter introduces nonlinearities in the estimation that prevent the use of the delta method to linearize the coefficients (Andrews, Stock and Sun, 2019). In our case, we assume that the system is non-linear regardless and thus do not rely on the same linearization assumption, especially so given that our estimator is implemented with maximum likelihood estimation and not 2SLS. As such, weak instruments are much less problematic than in the linear two-stage setting.

[19]We simply follow the victim/suspect identification as coded by GVA in our regressions. A simple analysis of a few specific, high-profile controversial DGUs shows that the victim/suspect classification may be adjusted to match the outcome of a trial, if there is one, or follow the way the altercation is portrayed in the media. Hemenway, Shawah and Lites (2022) found that the GVA reporting is overall accurate on a larger number of DGUs, providing confidence in the victim/suspect labeling despite some implicit judgment calls.

Table 4—Lethality of GVA defensive gun use incidents

	Armed robbery	Home invasion	Road rage	Bar/Club assault
Total number of incidents	19,801	9,502	2,698	8,701
DGU incidents	2,615	3,443	147	333
Victims killed	280 (.11)	241 (.07)	16 (.11)	86 (.26)
Victims injured	1,057 (.40)	754 (.22)	34 (.23)	317 (.95)
Suspects killed	1,040 (.40)	1,555 (.45)	49 (.33)	132 (.40)
Suspects injured	1,288 (.49)	1,839 (.53)	74 (.50)	124 (.37)
Non-DGU incidents	17,186	6,059	2,551	8,368
Victims killed	5,784 (.34)	2,264 (.37)	706 (.28)	3,279 (.39)
Victims injured	13,002 (.76)	4,692 (.77)	2,137 (.84)	10,861 (1.30)
Suspects killed	382 (.02)	403 (.07)	33 (.01)	124 (.01)
Suspects injured	765 (.04)	449 (.07)	53 (.02)	314 (.04)

Note: The average number of victims/suspects killed/injured per incident is reported in parenthesis.
Source: GVA (2023)

yields the same conclusion. Such proportions may seem intuitively high, which is consistent with GVA reporting only the most violent encounters, rather than being representative of the average crime. While it may be tempting to immediately infer that DGU thus protects victims and harms suspects, such proportions are subject to the endogeneity concerns mentioned earlier. For instance, if victims decide to use a gun defensively only in encounters where it is safe to do so, or if gun-wielders are only targeted by less-violent crimes in general, victim injury and death rates would be lower than in non-DGU cases *regardless* of the potential protective power of guns. Instead, one should turn to our instrumental estimates to verify this protective claim.

Table 5 presents the marginal effects of the instrumental variable regression in Panels B and C separated by type of crime, alongside a simple probit regression in Panel A that does not address endogeneity, for reference.[20] In Panel A, column 1, the estimated value of -.27 should be interpreted as showing that the baseline rate of victim death falls by 27 percentage points when the victim of an armed robbery pulls a gun in self-defense, while the figure of .15 shows that the baseline probability of suspect death increases by 15 percentage points. These figures may seem extremely high but are consistent with GVA recording only the most violent, shots-fired crimes and DGUs, where the baseline probability of death is much higher than typical in the universe of all adversarial encounters. Panels B and C report the average treatment effect (ATE) and the average treatment effect on the treated (ATET) obtained under our instrumental approach, respectively,

[20]As discussed previously, we only study the continental United States for which we have shooting range location data, and drop suicides and officer-involved shootings to focus on adversarial incidents between private citizens, resulting in fewer incidents than in Table 4.

Table 5—The effect of defensive gun use on crime (incident level)

	Armed robbery (1)	Home invasion (2)	Road rage (3)	Bar/Club assault (4)
A. Probit marginal effect				
P(Victim killed)	-0.27***	-0.31***	-0.19***	-0.20***
	(0.02)	(0.01)	(0.05)	(0.04)
P(Victim injured)	-0.31***	-0.43***	-0.48***	-0.25***
	(0.02)	(0.01)	(0.04)	(0.03)
P(Suspect killed)	0.15***	0.32***	0.09***	0.07***
	(0.00)	(0.01)	(0.01)	(0.00)
P(Suspect injured)	0.19***	0.35***	0.12***	0.10***
	(0.00)	(0.01)	(0.00)	(0.00)
B. IV marginal effect (ATE)				
P(Victim killed)	-0.31***	-0.34***	0.43***	-0.37***
	(0.03)	(0.03)	(0.00)	(0.01)
P(Victim injured)	-0.15	-0.62***	-0.75***	-0.48
	(0.16)	(0.00)	(0.01)	(0.77)
P(Suspect killed)	0.28	0.45***	0.13	0.56
	(0.25)	(0.01)	(0.17)	(9.99)
P(Suspect injured)	0.40*	0.38**	0.78***	0.20
	(0.21)	(0.15)	(0.01)	(0.13)
C. IV marginal effect (ATET)				
P(Victim killed)	-0.43***	-0.37***	0.18***	-0.97***
	(0.10)	(0.04)	(0.01)	(0.05)
P(Victim injured)	-0.16	-0.63***	-0.98***	-0.45
	(0.17)	(0.00)	(0.00)	(0.56)
P(Suspect killed)	0.33***	0.45***	0.25***	0.42
	(0.10)	(0.00)	(0.07)	(2.45)
P(Suspect injured)	0.42***	0.39***	0.77***	0.28***
	(0.10)	(0.13)	(0.03)	(0.06)
Number of incidents	15,173	6,971	2,072	6,755
Linear F-Statistic	0.33	2.19	0.61	6.52

Note: Instrumental variable probit model regressing binary incident outcomes on binary defensive gun use, using the driving distance to a shooting range as an instrument (see two-stage specification 1 and 2). Incidents are separated by type of crime. All controls, state fixed effects, and year fixed effects are included with coefficients presented in Online Appendix Tables A4 and A5. The same regression is run as a simple probit without the instrument to provide a baseline (Panel A). Controls, data, and sources are described in the text. Standard errors in parenthesis and clustered at the state level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

while columns 2, 3, and 4 present other types of crime, namely home invasion, road rage incidents, and bar/club assaults. We find that incidents where a gun is pulled in self-defense by the victim exhibit a significantly lower probability of death or injury for the victim(s) and a sizably higher probability of death or injury for the suspect(s). These results are unsurprising, given that we are estimating the effect of realized DGUs as the end product of the victim's optimization for personal safety, given the circumstances that present themselves. Thus, the homeowner who shoots the unarmed teen trying to climb in a window of what he thinks is an empty house is in a very different position from the robbery victim who suddenly is pistol-whipped with no chance to use a weapon even if he is armed. While our incident-level regressions will attribute the better outcome in the first case to the presence of a gun and the worse outcome in the second to the absence of a gun (since an unused but carried gun will not be counted as a DGU in the GVA data), much of what appears to be the benefit of DGU may simply indicate the more favorable circumstances in which it can be and is employed. Thus, we must consider these factors when interpreting the estimated difference between the probability of death/injury conditional on a gun being pulled and the probability of death/injury conditional on no self-defensive gun use for the average GVA victim. In cases where the suspect and victim are clearly defined—that is, armed robberies and home invasions—we estimate that the self-defensive use of a gun reduces the probability of victim death by 32 percentage points (p.p.) and the probability of victim injury by 30 p.p., while increasing the probability of suspect death by 33 p.p. and the probability of suspect injury by 39 p.p., based on a weighted average of the ATE. The net change in the overall fatality of the incidents thus remains unclear, since the two effects come close to balancing out. While the probabilities are rather consistent across types of crime, road rage and bar/club assaults show much more outcome variability, likely due to the diversity of these incidents and the lack of clearly defined suspect and victim roles. Moreover, there is some evidence that the self-defensive use of a gun in a conflict stemming from road rage might serve to escalate more than it protects, increasing the probability the victim gets killed.

However, such a granular picture ignores all indirect effects of defensive gun use. That is, it computes the reduced probability of being killed due to self-defense conditional on a crime being committed. This condition has several implications. Whether a higher rate of carrying by the population deters crime preemptively or increases it by supplying more guns to criminals, as pointed out by conflicting strands of the literature, our incident-level regression will fail to detect either effect, as long as the marginally induced or prevented offense are as deadly as baseline crime. Moreover, examining individual encounters does not capture potential changes in the composition of crime. For instance, if more guns encourage criminals to switch from nonconfrontational property crimes to armed robbery, holding constant the overall number of gun crimes, our regression would not pick up any change in mortality or injury rates as long as they remain unchanged within each crime type. Finally, there is no way to measure the passive deterrent effect of frequent gun carrying at the incident level, as discussed previously.

Overall, the incident-level regression provides an incomplete view that is biased in the direction of a more favorable assessment of defensive gun use. On the one hand, guns may be even more efficient on the aggregate by deterring crimes preemptively. On the other, the same behaviors that enable DGU—widespread gun ownership and carrying—may increase the overall number of guns in the hands of criminals, increasing in turn the total number of citizens who fall victim to crime.

IV. The Aggregate Effect of Defensive Gun Use on Crime

In order to compute the total effect of defensive gun use on crime, we aggregate our data to the county level. That is, we study the effect of a higher number of DGU incidents per 100,000 inhabitants on the number of victims, injuries, and violent crimes committed per 100,000 people. We use the number of shooting ranges per 100,000 population as an instrument for defensive gun use. As discussed in section II, we control for various demographic and geographic characteristics to make the instrument exogenous.

In contrast to the previous section, we turn to a standard instrumental variable approach since our variables are now continuous. Our two-stage least-squares specification is

$$\mathrm{w}_c = \alpha + \beta \mathrm{NDGU}_c + \mathbf{X}_c'\mathbf{\Gamma} + \sum_{s=1}^{S-1} \mathbb{1}_{c \in s}\alpha_s + \varepsilon_c \,, \tag{3}$$

$$\mathrm{NDGU}_c = \mu + \delta \mathrm{SR}_c + \mathbf{X}_c'\mathbf{\Pi} + \sum_{s=1}^{S-1} \mathbb{1}_{c \in s}\mu_s + \nu_c \,, \tag{4}$$

where w_c denotes the variable of interest (number of victims/suspects killed/injured or number of gun-involved incidents (total or by type), both per 100,000 inhabitants) for counties $c = \{1, .., C\}$, NDGU_c is the number of defensive gun uses per 100,000 inhabitants, $\mathbf{X}_c$ is a 13×1 vector of controls (state firearm ownership rate, county density, average rent, median household income, Republican vote in 2016, ratio of firearm suicides over all suicides, and the share of population that is male, aged 18-25, aged 35-55, White, Black, Hispanic, or homeowning), and SR_c is the number of shooting ranges per 100,000 inhabitants.[21] We include state fixed effects α_s, μ_s for states $s = \{1, ..., S\}$, removing one state to avoid collinearity, and weight the counties by their respective populations. We additionally cluster our standard errors at the state level, since counties' outcomes within the same states are likely to be correlated. Formally, these variables are directly related to the individual-level specification. The total number of defensive gun uses per 100,000

[21] For two reasons, we scale defensive gun use by population rather than total crime figures such as those provided by UCR. First, since population density generally correlates positively with criminal behavior, it is unlikely that a very densely populated county would see very few crimes and thus mechanically very few defensive gun uses. Second, while the Gun Violence Archive data is imperfect, the reporting imperfections are at least consistent across our variables. Expanding our data universe to include a second source would introduce dynamics we cannot control for in any way.

inhabitants is defined as

$$\text{NDGU}_c := \frac{100,000}{\text{population}_c} \sum_{i=1}^{N} \mathbb{1}_{i \in c} \text{DGU}_i \ ,$$

while the outcome variables are the sum of the observed characteristics of the incidents

$$\text{w}_c := \frac{100,000}{\text{population}_c} \sum_{i=1}^{N} \mathbb{1}_{i \in c} \text{y}_i \ ,$$

where y_i is extended to additionally include the type of crime and unlawful possession, which we previously used to separate the regressions. The distance to the nearest shooting range ΔSR_i is negatively correlated with the density of shooting ranges in county SR_c, since we expect dense counties to have a lower mean distance to shooting range, but there is no formal relationship between the two.

Table 6 presents the full results of our instrumental variable regressions, including the controls and baseline OLS. We estimate that areas with more defensive gun uses are associated with more overall violent crimes, as well as more armed robbery, more home invasion, more road rage, more bar fights, more victim deaths, and more victim injuries. Moreover, while these results all emerge in our OLS regressions (the first row of Table 6), the magnitudes all rise substantially when we use our instrument (the second row of the same table).

In stark contrast to our incident-level results, our aggregate county-level analysis[22] generates a uniformly bleak assessment of increased defensive gun use: specifically, we find that an increase of one defensive gun use leads to nearly 10 more victim fatalities and 33 more victim injuries (all per 100,000 population). Ultimately, we interpret this coefficient to imply that an increase in gun carrying—conditional on gun ownership—produces an increase in crime victim injuries and fatalities scaled by population. Moreover, suspect injury and fatality rates increase far less dramatically than victim injuries and deaths. This would be expected if criminals in high-DGU areas anticipate resistance, and therefore arm themselves at higher rates and preemptively attack with more force. The increasingly armed criminals might also become better at selecting targets who are less likely to be armed, leading to spillover effects in which non-DGU incidents become more violent or lethal. Importantly, Table 6 shows no indication of any deterrence in any of the individual categories—armed robbery, home invasion, road rage, or bar fights—all of which increase in the aggregate with more defensive gun use.

Donohue et al. (2023) suggest that this enabling effect of defensive gun use is likely generated by both providing more guns to criminals through theft and

[22]We notably drop about 600 countries due to CDC suppression of low counts of firearm suicide data. Nonetheless, all of our results are robust to removing this control and using about 90% of the approximately 3,100 counties in the US instead (see Online Appendix III).

TABLE 6—THE EFFECT OF DEFENSIVE GUN USE ON CRIME (AGGREGATE LEVEL), 2014-2023

	Victims killed	Victims injured	Suspect killed	Suspect injured	Gun-related incident	Armed robbery	Home invasion	Road rage	Club incident	Unlawful possession
OLS										
Defensive gun use	5.13***	12.49***	0.42***	0.68***	15.03***	1.11***	0.49***	0.17***	0.35***	0.38***
	(1.13)	(2.51)	(0.01)	(0.03)	(2.71)	(0.10)	(0.03)	(0.03)	(0.04)	(0.07)
IV										
Defensive gun use	9.76***	32.93**	0.52***	0.73***	35.99**	2.32***	0.85***	0.45***	0.73***	1.59**
	(3.55)	(14.92)	(0.07)	(0.14)	(15.17)	(0.65)	(0.20)	(0.15)	(0.18)	(0.69)
Density	-115.25	239.37	11.80	-30.45*	133.13	-0.25	5.46	13.75	-52.43**	12.75
	(345.42)	(1386.36)	(8.40)	(15.74)	(1393.10)	(50.63)	(19.35)	(14.35)	(21.53)	(60.63)
Rent	-16.16**	-16.21	-0.02	-0.77**	-24.36	-1.50	-0.39	0.52	-0.57	-1.54
	(8.17)	(37.64)	(0.27)	(0.33)	(36.33)	(1.53)	(0.61)	(0.45)	(0.66)	(1.68)
% Male	-2.31	-204.98	3.21	-4.15	-204.47	-8.66	-0.02	1.57	2.48	-19.80
	(98.40)	(427.79)	(2.65)	(4.56)	(428.18)	(14.82)	(5.76)	(2.76)	(6.37)	(18.43)
% 18-25 years old	-92.28	-72.23	1.93	-3.60	-125.60	6.53	8.07**	2.87	-4.21	16.19
	(66.99)	(229.80)	(1.71)	(2.87)	(239.22)	(10.52)	(3.56)	(2.94)	(4.05)	(11.47)
% 35-55 years old	-54.32	-51.76	3.17	-15.01***	-102.40	-1.20	1.83	10.51***	-10.11	-9.99
	(99.74)	(339.65)	(2.74)	(4.13)	(356.78)	(14.64)	(5.66)	(3.84)	(7.76)	(17.49)
% White	13.40	24.82	-0.65	-0.08	31.45	-1.34	-1.66*	-0.91	-0.28	-3.13
	(31.74)	(96.61)	(0.66)	(1.24)	(101.93)	(3.99)	(0.97)	(1.04)	(1.49)	(3.76)
% Black	147.05**	162.57	-1.29	2.91	233.57	4.11	-4.23	-3.66	1.06	-7.93
	(68.51)	(261.26)	(1.38)	(2.56)	(268.52)	(10.67)	(3.07)	(2.48)	(3.52)	(12.08)
% Hispanic	11.56	24.46	0.09	-0.19	22.84	2.08	-0.43	1.04	0.73	-0.77
	(10.65)	(42.12)	(0.30)	(0.37)	(40.46)	(2.27)	(0.68)	(0.65)	(0.64)	(1.92)
% Homeowner	-6.06	-31.65	1.43	-3.75**	-35.25	-2.91	0.08	1.09	-4.63**	-2.14
	(31.44)	(101.73)	(0.90)	(1.52)	(104.48)	(4.22)	(1.26)	(1.38)	(2.08)	(5.52)
Median household income	72.68	1.55	-0.22	14.25**	40.93	59.10**	3.36	-1.92	14.22	31.68
	(168.16)	(669.73)	(5.67)	(7.02)	(663.54)	(25.63)	(10.45)	(6.83)	(12.14)	(30.26)
Firearm suicide rate	-17.03	-87.84	-0.02	0.31	-89.67	-1.06	1.91***	0.21	-0.20	-1.59
	(16.69)	(53.90)	(0.39)	(0.79)	(56.60)	(2.03)	(0.67)	(0.50)	(1.05)	(1.92)
Republican vote	-25.36	-59.25	0.29	-0.44	-59.62	-0.53	1.64	0.13	-1.86	6.29
	(17.24)	(64.94)	(0.44)	(0.80)	(67.26)	(3.54)	(1.42)	(0.87)	(1.36)	(4.00)
State firearm ownership	315.51**	1529.73***	-7.38***	-6.48	1508.76***	92.58***	6.32	15.87***	19.04**	66.87***
	(130.47)	(521.64)	(2.75)	(5.65)	(539.94)	(24.94)	(7.50)	(5.99)	(7.76)	(25.54)
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of counties	2247	2247	2247	2247	2247	2247	2247	2247	2247	2247
Robust F-Statistic	10.60	10.60	10.60	10.60	10.60	10.60	10.60	10.60	10.60	10.60

Note: Instrumental variable model regressing aggregate incident outcomes on aggregate defensive gun use, using the density of shooting range in county as an instrument (see two-stage specification 3 and 4). All variables are in unit per 100,000 inhabitants. The same regression is run without the IV to provide a baseline. Regression uses county population as an analytic weight. Rent is in thousands; density and household income are in millions. Controls, data, and sources are described in the text. All of the data for the dependent variables is aggregated to the county level and comes from the GVA. Results without controls or fixed effects are presented in Online Appendix Table A6 Standard errors in parenthesis and clustered at the state level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

increasing their level of gun carrying, while simultaneously diminishing the effectiveness of law enforcement as police respond to the greater risks from a more armed public. After controlling for gun ownership at the state and county level, variation remains in the frequency with which those guns are carried—on the street, in vehicles, concealed in clothing or displayed openly rather than stored in a gun safe at home. Large swaths of the literature have demonstrated that increasing the stock of guns carried, often by relaxing the requirements to own and/or carry them, has a downstream effect leading to more stolen guns used in crimes. The Gun Violence Archive also collects information on law enforcement seizures of unlawfully possessed firearms[23] as well as whether the unlawful possession (such as by a felon or other prohibited person) was discovered in the commission of another offense. The results in the last column of Table 6 indicate that areas with more defensive gun use are associated with a higher number of arrests for unlawful possession—and instrumenting quadruples the magnitude seen in the OLS results of the first row. This provides evidence in support of the stolen-guns channel hypothesized by Donohue et al. (2023) and Billings (2023): more guns in the hands of law-abiding citizens means more guns stolen from law-abiding citizens, and eventually more guns used to commit more violent crimes. A second channel relies on criminals using legally-acquired guns to commit crimes, although previous research by Cook (2018) points towards the stolen-gun channels dominating legal channels. Finally, O'Flaherty and Sethi (2010) provide game-theoretic foundations for premature use of force when adversaries are perceived as more dangerous; to avoid being victimized themselves, agents make snap judgments in favor of preemptive violence. These mechanisms would reconcile our strikingly different aggregate and individual results, even though we are only able to assess the stolen-gun channel through our observation of unlawful possession.

Crucially, given the limitations of our data, we place greater emphasis in assessing the overall effect of guns being carried and used on the direction of our coefficients as opposed to their exact magnitudes. Because GVA only records the most active and violent instances of defensive gun use, our individual-level sample is biased towards the most violent gun crimes, as discussed in the previous sections. However, at the aggregate level, it is likely that these active instances of defensive gun uses are strongly correlated with unrecorded passive defensive gun uses. That is, areas with higher numbers of violent defensive gun use are also likely to have a large number of passive defensive gun uses and gun carrying, which could potentially further deter crime preemptively or enable it through gun theft since more guns are carried. As such, our regression estimates capture the effect of the increased carrying of guns—despite it not being directly measured in our regression—as it is proxied by active defensive gun use. Therefore, it is not that a single additional instance of DGU in a county with 100,000 inhabitants would directly cause the death of 9.76 victims, but rather the full array of

[23]This includes both local police seizures as well as the federal Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) seizures.

behavioral changes in gun carrying and use by potential victims, criminals, and the police that leads to these adverse outcomes. Thus, we study how areas with a higher number of guns being carried and used, conditional on ownership, are associated with more fatalities and violent crime. The size of the coefficient thus captures many of the indirect and passive effects of defensive gun use, far beyond the firing of a single weapon. In this sense, our aggregate results provide a view of the total impact of more guns carried and used by law-abiding citizens in general, whereas the interpretation of our incident level regression results in Table 5 is severely limited by the universe of violent defensive gun use and only captures direct effects.

V. Conclusion

In answering whether guns enable or deter crime, researchers have typically divided their focus between the opposing direct and equilibrium effects. Our results suggest that, at least in the limited set of extreme cases captured in the GVA data, guns may directly inhibit crimes that are already being committed, even while guns overall indirectly increase the total number and severity of crimes in the population. This postulate partially explains the stark contradictions that arise from the literature as well as the public debate.

Our estimates pertain to "best case scenario" defensive gun use—situations when the attacker may or may not also be armed with a firearm, and when the defender is more relatively capable than the average potential victim. Recall that the criteria for inclusion in the Gun Violence Archive mean that perpetrators are carrying a firearm in about two-thirds of defensive gun use cases, but are always carrying in non-defensive cases, so outcomes (particularly victim injury/fatality likelihoods) are only partially comparable between the two types of encounters. Thus, we present an upper bound on the protective power of defensive gun use based on validated occurrences, while still finding that the aggregate effect of guns purchased for self-protection is socially harmful.

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