Gun Dealer Density and its Effect on Homicide

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Abstract

We explore the relationship between gun prevalence and homicides in the United States from 2003–2019. Unlike previous research, which typically uses an indirect, state-level measure of gun prevalence, we use a direct measure of guns in a narrow geographic area: gun dealers. We find an increase in gun dealer density is significantly and positively associated with increased homicides in subsequent years. We compare estimates from our preferred measure, the number of dealers per 100 square miles in a local area, to those found using other gun prevalence measures. We find our preferred measure to be more consistent in magnitude across three different estimation methods and two different data sources. We additionally show the effect of gun dealer density is limited mostly to counties that have a high percent of Black residents. We propose that the so-called "Ferguson Effect"—a sharp increase in violent crime in urban and Black communities after 2014—might be partially explained by an influx of gun dealers in and near Black communities, rather than just a change in the propensity of Black residents to call the police or changes in police behavior.

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1 Introduction

The declining trend of gun violence throughout the 1990s sharply changed course at the turn of the century. Although the gun violence discussion in the United States is often dominated by mass shootings, the increase in gun deaths over the past 20 years is an order of magnitude larger than what can be explained by mass shooting incidents. Comparing gun-related deaths from the trough in 2000 to the most recent numbers available in 2019, gun-related deaths have increased by more than an additional Sandy Hook shooting, on average, per day.[1] This disturbing trend makes the study of the relationship between firearm availability and violent death more important than ever. Yet much of the literature on firearms—particularly concerning its connection to homicide and crime—is full of null and mixed results. There are many possible explanations for this, and among them is the possibility that existing measures of gun availability are fundamentally flawed. We propose a simple, but powerful, alternative measure: gun dealer density, as measured by the number of gun dealers per 100 square miles in a county and in a small region around a county.

A persistent difficulty in studying gun violence in the United States is that there is no standard measure of gun availability. While the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) tracks the number of firearms manufactured in and imported into the US, researchers have no record of how these weapons are geographically distributed or how that distribution changes over time. Thus, gun ownership/availability is proxied using a variety of methods or measured using self-reported survey data.[2] Generally, these proxies suggest a positive relationship between gun ownership and suicides. However, the relationship between gun ownership and homicides is often noisy or non-existent when using plausibly causal statistical estimation methods. These discrepancies give us reasons to question whether we actually have a firm understanding of the relationship between gun availability and homicides; arguably, this is rooted in problems that are inherent to the data used to estimate the relationships.

Using publicly available data from the Centers of Disease Control and Prevention (CDC), the United States Census Bureau (USCB), Federal Bureau of Investigation (FBI), and data from the ATF, we construct a seventeen-year panel running from 2003 to 2019. Our panel tracks each US county's homicides, demographics, criminal activity, and Federal Firearm Licenses (FFLs) and contains over 50,000 county-years. For each county-year, we also construct a measure of gun density based on the number of FFLs, the land area of the county and surrounding counties. With these data, we estimate county homicides with a series of regressions, using county-level fixed effects, to account for unobserved time-invariant heterogeneity. Our main results show that a one unit increase in the number of gun dealers per 100 square miles increases homicides by between 2.1 percent and 4 percent. These results are robust to multiple specifications and data sources. We also find that gun density has no effect on non-gun homicides and that the relationship is not

[1] There were 11,044 more gun-related deaths in 2019 than in 2000, which equates to 30.3 additional gun-related deaths on average per day.

[2] Common proxies in the economics and public health literature include the percentage of suicides that were committed with a firearm (e.g., Siegel et al., 2013), subscriptions to gun interest magazines (e.g., Duggan, 2001), self-reported survey data (e.g., Mocan and Tekin, 2006) and queries to the National Instant Criminal Background Check System (NICS) (e.g., Lang, 2013, 2016). We discuss this literature more thoroughly in Section 2.

caused by changes in business activity (as measured using business establishments per 100 square miles). Last, we explore whether or not gun dealer density interacts with local characteristics. We find that our results are driven primarily by the relationship of our measure of gun density and the homicide rate in counties with a relatively high percent of Black residents, with the marginal effect more than 1.5 times higher for counties with the the largest proportion of Black residents. We show this is due to a larger variation in gun availability in these county areas and propose that the so-called "Ferguson Effect"—an explanation for increase in violent crime in Black communities after death of Michael Brown—may be largely attributed to a massive spike in gun availability around Black communities shortly before 2014.[3] Additionally, we provide evidence that the composition of gun dealers in these communities changes, such that large, corporate dealers leave and are replaced by independent "defense" oriented dealers.

Our study makes several significant contributions. Unlike the majority of past work involving gun deaths, we use county-level data. We do so because there is substantial heterogeneity in terms of county characteristics (e.g., population, income, racial demographics, and gun availability) within states. This approach allows for more precise estimates of the effect of guns due to the increase in the number of observations, improved demographic controls, and a greater ability to capture unobserved heterogeneity within states, which makes the conditional invariance assumptions (pointed out by Manski and Pepper (2018)) more plausible. Second, as we will discuss shortly, our gun prevalence measure has numerous advantages over previously used measures, as common proxy variables are likely picking up demographic differences rather than actual gun pervasiveness. As far as we know, by using gun dealer density, we are the first to use a nearly direct measure of the number of guns in a narrow geographic area in a plausibly causal framework. Finally, we are able to show that large increases in gun density in Black communities is a likely explanation for the increasing homicide rate in those areas after 2014.

2 Background

In 2019, there were nearly 40,000 deaths involving firearms in the United States. Of these deaths, over 60 percent were suicides; about one-third were assaults/homicides, and the remaining share were due to various other causes (e.g., accidents). Firearms play a particularly important role in the occurrence of violent deaths because of how effectively they cause mortal damage. All else equal, an individual intent on violent action would likely choose a gun over any other weapon for this reason. Thus, variation in the costs associated with locating and acquiring a gun will presumably predict differential levels of violent death. In other words, areas with greater gun availability—and consequently a lower cost of acquiring a gun through primary or secondary markets (e.g., through private sales or theft)—will likely have more gun-related violent acts. Even if individuals substitute into using other weapons/methods when guns are less available (e.g., using a knife instead of a gun when committing a murder), survival rates are quite different across methods of suicide

[3]The Ferguson Effect is a term coined by chief of the St. Louis police to suggest that the spike in homicides and other violent crime was due to an increased hesitancy of police officers to enforce the law due to media and legal scrutiny after the shooting of Michael Brown in Ferguson, MO. The term is also used to described a decreased willingness of individuals in these communities to call or cooperate with police.

and homicide, leading to fewer deaths. For instance, Band et al. (2014) finds that 33 percent of those admitted to trauma centers in Philadelphia for gunshot wounds died compared to only 7.7 percent who died after suffering a stab wound. Given the differential survival rates, it is reasonable to assume that a gunshot is more likely to result in a fatality compared to other violence-related injuries. Consequently, even if all individuals with violent intent substituted for other weapons, we would still expect a decrease in firearm availability to decrease overall deaths due to other methods being substantially less effective than firearms. However, while there is a general consensus of research demonstrating a strong relationship between gun prevalence and suicides (e.g. Anglemyer et al., 2014; Lang, 2013; Briggs and Tabarrok, 2014; Miller et al., 2013; Phillips, 2013), the effect of greater gun availability on homicides continues to spur debate (e.g. Lott and Mustard, 1997; Ayres and Donohue III, 2002; Duggan, 2001; Moody and Marvell, 2005; Siegel et al., 2013; Lang, 2016).

Much of the debate around the relationship between gun availability and violent death is likely due to the lack of an accurate measure of the stock/flow of guns in the United States. We can be certain that the United States, as a whole, has a large stock of firearms.[4] However, there is no direct data to indicate how this stock of weapons is distributed throughout US states and counties. As an alternative, researchers often try to use proxy measures of the flow of guns in (and out) of communities and rely on statistical methods, like area-level fixed effects, to control for the existing stock of guns. This makes the accuracy of the proxy of paramount importance. Common proxies include the percentage of suicides committed with a firearm (e.g., Azrael et al., 2004; Siegel et al., 2013), subscriptions to gun interest magazines (e.g., Duggan, 2001), self-reported survey data (e.g., Mocan and Tekin, 2006), queries to the National Instant Criminal Background Check System (NICS) (e.g., Lang, 2016), and hunting permits (e.g., Siegel et al., 2014). Each of these measures presents a particular drawback, however. The "gold standard" gun measure–particularly in the public health and sociology literatures–is the ratio of gun suicides to total suicides (Azrael et al., 2004). Using the proportion of gun suicides to proxy for gun ownership is troublesome due to the measure being highly correlated with demographics (suicide rates are highest among middle-age white men)[5], introduces a potential statistical tautology (e.g., using a transformation of gun deaths to predict gun deaths), and will possibly over-estimate the prevalence of guns in areas with few suicides (see Lang, 2013; Edwards et al., 2018; National Research Council, 2005). The relative lethality of guns compared to other suicide methods becomes an issue as well.[6] This suggests that—unless the number of suicide attempts never changes—the gun suicide ratio is *wholly inappropriate* for use in examining changes in gun

[4] The Small Arms Survey estimates that there are nearly 400 million privately-held firearms in the US, and that the US has more than double the number of firearms per person than any other nation. See `http://www.smallarmssurvey.org/fileadmin/docs/T-Briefing-Papers/SAS-BP-Civilian-Firearms-Numbers.pdf` (accessed September 11, 2021).

[5] See `https://afsp.org/suicide-statistics/` (accessed September 11, 2021)

[6] Consider a hypothetical area that has 100 total suicides, 60 of which are committed with a gun, making the gun suicide ratio 0.6. Now imagine a mental health shock in which all suicide attempts increases by 50 percent. This would mean 30 additional suicide attempts with a gun and 20 additional suicide attempts by other means. Miller et al. (2013) show that suicide attempts by firearms are about 85 percent lethal, while suicide attempts by any other means are only 9 percent lethal. Thus, approximately 26 new gun suicides and 2 new non-gun suicides are recorded, bringing the gun suicide ratio $86/128 = 0.67$. So an increase in suicide attempts would make the gun-suicide ratio increase by 12 percent despite there being no change in the ratio of suicides *attempted* with a gun.

prevalence over time. Finally, as we show in Section 2.1, the gun suicide ratio suggests guns are most available in rural white areas away from large population centers, which contradicts what we know about patterns of gun-related crime and commerce.

Measures based on survey data have their own problems: i) there is no guarantee that respondents truthfully report whether they own a gun, and ii) survey coverage is limited at best. For example, one of the large surveys, the Centers for Disease Control's Behavioral Risk Factor Surveillance System, has only asked about firearm access two times since 2002 (2004, and 2017). Further, respondents only come from a handful of US counties. Magazine subscriptions may have been a reasonable proxy at one time, but have probably become less relevant in the digital age as the type and scope of media changes. Hunting permits may seem like a reasonable measure of gun density, but they tend to identify a particular type of gun owner (or local interest in outdoor activities) rather than local gun ownership. Furthermore, while many of these measures were validated using Generalize Social Survey (GSS) data and National Rifle Association (NRA) memberships, these validations are dubious at best because i) the GSS is designed to be nationally representative but is not necessarily representative of individual states or areas, ii) NRA members are not representative of gun owners as a whole, and tend to be largely older, white, and heavily conservative (Parker, 2017), and iii), hunters are 90 percent male, mostly middle-aged, and 97 percent white. So, like the gun suicide ratio, magazine subscriptions and hunting permits are primarily going to measure the demographic characteristics of the region, rather than gun ownership, per se.

Arguably, the single best measure of gun availability used in the literature thus far is the number of queries to the NICS system, made popular by Lang (2013, 2016). NICS checks are done, by federal law, before any firearm is sold by an FFL dealer. The advantages of this measure is that it shows a direct interest in firearm purchases or legal transfers by mail, and it is available, from the FBI, at the state level every year since 2004. However, its major disadvantage is that it cannot measure the heterogeneity of gun availability within states, which we show can be substantial. It also misses private transfers of firearms, which do not currently require a NICS check. Finally, recent investigative reporting has shown that violations of background check requirements by FFL dealers are surprisingly common and that ATF officials rarely impose serious penalties for violations. A recent investigative report published in USA Today and the Trace found that, on average, only about 12.3 percent of FFLs are inspected by the ATF. Among the inspected, 33.5 percent were cited for violations. The vast majority of those cited are only issued warnings. Only about 3 percent of violators are recommended to have their license revoked, and nearly 60 percent of those recommendations are overruled, with a warning issued instead.[7] According to ATF records, nearly 84,000 guns were reported lost or stolen from FFLs from 2015-2019, nearly 17,000 per year. Thus, NICS checks may not be accurately capturing market activity (both legal and illegal) for guns, even if analysis state level was ideal.

Because of the problems associated with these proxies, attempts to estimate the relationship between gun prevalence and homicides have, unsurprisingly, produced mixed results. For instance, Siegel et al. (2013), using the gun suicide ratio, Siegel et al. (2014), using hunting permits and the gun suicide ratio, and Duggan (2001), using magazine subscrip-

[7] See `https://www.usatoday.com/in-depth/news/investigations/2021/05/26/gun-dealers-let-off-hook-when-atf-inspections-find-violations/7210266002/` (accessed on June 12, 2021).

tions, all find that an increase in gun prevalence is associated with an increase in homicides. However, using an imputed measure of gun availability based on the General Social Survey, Moody and Marvell (2005) find that handguns have no significant effect on crime. Similarly, Lang (2016) finds a small and insignificant effect of gun availability—measured by NICS checks—on homicide. We attempt to resolve these issues by focusing on a related, but arguably superior measure: the number of FFLs in an area.

2.1 Federal Firearms Licenses

FFLs are licenses issued by the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF). These licenses permit individuals and companies to engage in firearm-related business. Currently, there are nine different types of FFLs. A description of each type along with the current cost is found in Table 1. FFLs are valid for three years and can be renewed.[8] In February of 2019, there were 79,405 FFLs—not including Type 3s—in the United States.[9] The two types of FFL license considered to be "dealer" (i.e. able to buy and sell from the public and receive shipments of firearms) licenses are the Type 1 license (for dealers and gunsmiths) and the Type 2 license (for pawnbrokers).[10]

FFLs are common in the United States, and obtaining one takes about 60 days from application to approval. Applicants must first submit the application form along with the correct application fee. After the fee is processed, the applicant's information is entered into the Federal Firearms Licensing Center's (FFLC) database. For all license types, except for the Type 3 license, the ATF reviews substantial supporting material which includes fingerprints and photographs. The FFLC then conducts an electronic background check on all of the "responsible persons" identified in the application.[11] While the background checks are being completed, a local Industry Operations Investigator (IOI) is sent to conduct an in-person interview with the applicant. Upon completion of the interview, the IOI makes a recommendation regarding the outcome of the application. The license is issued once the background check(s) have been completed and the applicant demonstrates that all business operations comply with state and local law. For additional information regarding how we acquired the data and how the licenses themselves are structured, see the Appendix A.1.

We focus our attention only on Type 1 and Type 2 licenses (dealer and pawnbroker). These represent the number of establishments conducting retail sales of firearms to the public, so the number of establishments in business serves as a reasonable proxy for the flow of firearms. This would capture the same variation as NICS checks, but we are able to obtain the street address of every FFL in the United States, which allows us to measure the heterogeneity of gun availability within each state. Additionally, firearms require repair and maintenance (gunsmithing) and are routinely sold or traded, and these services require

[8] In most cases, renewal fees are the same as the initial license costs, the only exceptions being Type 1 and Type 2—both of which cost $90 to renew.

[9] Type 3 licenses are for firearm collectors acquiring firearms for non-commercial purposes (see Appendix A.1)

[10] A pawnbroker license is in every way identical to a dealer license, but additionally allows the licensee to engage in the pawning of firearms (i.e., receiving a firearm as collateral for a loan). The licensee also must demonstrate compliance with local laws about pawn establishments, which are often different than other types of businesses.

[11] The ATF defines a responsible person as "a sole proprietor, partner, or anyone having the power to direct the management, policies, and practices of the business or activity as it pertains to firearms."

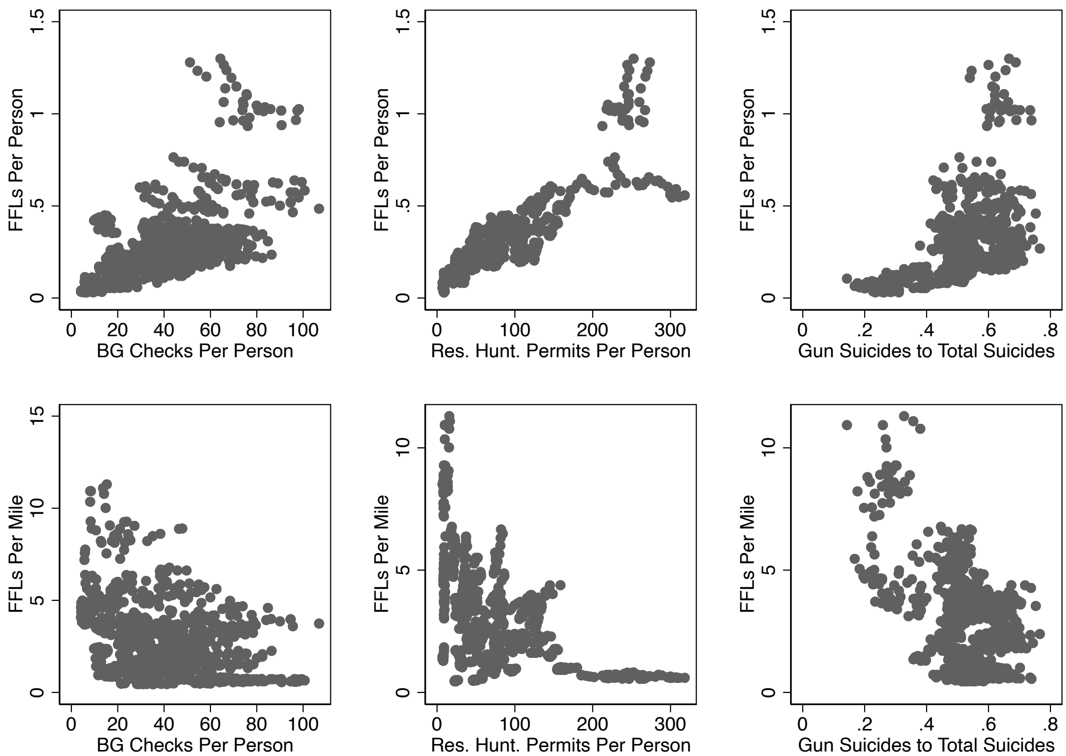
Table 1: FFL Types

Type	Cost	Description
Type 1	$200	Dealer in firearms / Gunsmithing (firearms repair)
Type 2	$200	Pawnbroker
Type 3	$30	Collector of curios and relics
Type 6	$30	Manufacturer of ammunition for firearms
Type 7	$150	Manufacturer of firearms & ammunition
Type 8	$150	Importer of firearms & ammunition
Type 9	$3,000	Dealer in destructive devices
Type 10	$3,000	Manufacturer of destructive devices, ammunition for destructive devices, or armor piercing ammunition
Type 11	$3,000	Importer of destructive devices, ammunition for destructive devices, or armor piercing ammunition

a Type 1 or Type 2 license if being done for any reason other than a private exchange. Further, firearms components, accessories, and ammunition are also typically sold at FFL establishments, despite not requiring a FFL license. Last, online sales of firearms require the firearm to be shipped to a FFL holder before the transfer is completed. Thus, the number of businesses with these license types also serves as a proxy for the stock of firearms in an area, even the presence of firearms that would not require a NICS check and firearms transferred to individuals without a NICS check for either accidental or negligent reasons.

We first note that FFLs (collapsed at the state level) and NICS checks are highly correlated, which can be seen in the top left corner of Figure 1. This suggests that FFLs are capturing the same variation as NICS checks, but are able to do so at a more localized level. Additionally, Figure 1 shows that FFLs per person and FFLs per 100 square miles are both highly correlated with several existing measures of gun density and themselves (state level: r=-0.50; county level: r=-0.22). Graphically, the correlations between common measures of gun prevalence and FFL density (both population and geographic) are presented in Figure 1. The direction of the correlations depends on whether gun density is measured using FFLs per 100 miles or FFLs per 100,000 people—which is not surprising considering the geographic size of rural counties in the United States. Simple Pearson correlations validate

Figure 1: Correlation of Common Measures of Gun Density vs FFL Density



Notes: Correlation between FFLs per 1,000 people (100 miles) and existing measures of gun prevalence (2003-2019; $n = 850$). From top left to bottom right, long-gun and handgun background checks per person vs FFLs per 1,000, hunting permits per capita vs FFLs per 1,000, percent gun suicides vs FFLs per 1,000 people, long-gun and handgun background checks per person vs FFLs per 100 miles, hunting permits per capita vs FFLs per 100 miles, and percent gun suicides vs FFLs per per 100 miles.

what is observed in these figures: i) the correlation between long-gun and handgun background checks per person and FFLs per 100,000 people (100 miles) is .63 (-0.35), ii) the correlation between FFLs per 100,000 people (100 miles) and hunting permits per capita is .85 (-.486), and iii) the correlation between FFLs per 100,000 (100 miles) and the proportion of gun suicides is .48 (-.43). The negative correlation between the per capita measures and the area measures highlights some potential problems with using per capita measures for gun availability, which we will describe in the next section. What likely matters is not how many guns there are per person, but how easy it is for a person with the opportunity to commit a crime to get a gun easily.

While, to our knowledge, this is the first study in the economics literature to use FFLs as a proxy for gun availability, the idea has been previously explored in sociology/criminology and public health.[12] These papers all use single-year or pooled data with cross-sectional

[12] We came up with our concept independent of this literature. Despite this, many of the same ideas and logic from this section and the next section for using FFLs as a gun prevalence proxy are found in these papers as well, which we take as validation of the concept.

statistical methods that cannot be interpreted causally. Furthermore, each paper standardizes the number of FFLs into the number of FFLs per capita, which, as we discuss in Section 2.2, likely underestimates gun prevalence in large population centers. Nonetheless, there are several interesting methods and results from this literature worth noting. Most of these papers find no association between the number of FFLs per capita and homicide (e.g., Chao et al., 2019; Wiebe et al., 2009; Semenza et al., 2020). However, Semenza et al. (2020) finds that gun dealer prevalence is associated with increased homicides for white victims only, and Stansfield and Semenza (2019) and Stansfield et al. (2021) find that an increase in gun dealers is associated with a greater number of intimate partner homicides. Steidley et al. (2017) is the only paper that finds that increased gun dealer prevalence is associated with increases in the overall homicide rate. Their approach is unique in that they focus their study on major cities only and differentiate between different types of gun dealers, like pawn brokers and "big box" retailers—a concept that we explore to some extent as well in Section 4.3. Steidley et al. (2017), Wiebe et al. (2009), and Semenza et al. (2020) are also unique in that they recognize that gun prevalence in the entire local region around the county or city matters, which we discuss in the next section. Matthay et al. (2021) is an exception in this literature for being the first to use FFLs as a measure of gun availability in a quasi-experimental framework. They combine monthly data on self-harm injuries with FFL data in California and use a difference-in-differences approach—comparing incidents of self-harm in counties that had a new FFL dealer to matched counties with no change in FFLs in the month before the new FFL opening and the month after. They find no statistically discernible effect of FFL openings on self-harm.

2.2 Gun Density

The effectiveness of firearms in causing fatal injury makes them the preferred tool for individuals intending to cause violence. Thus, variation in the cost of locating and acquiring guns relative to other weapons should be a cogent predictor of gun-related deaths. For this reason, we choose to focus on *gun density*—a measure of the distribution of firearms in a region using FFL data—as the relevant explanatory factor in gun deaths rather than FFLs per person. We do this for two reasons: first, the concentration of gun dealers in an area will strongly correlate with the price of the firearm on the margin, due to competition, and the search costs of finding a particular gun. Second, FFLs per person is highest in areas with low population density and known for sport shooting and hunting tourism, like Montana, which would not necessarily correlate with a high volume of weapons per se and, like the measures discussed previously correlate with demographics.[13]

As a "first pass" measure of gun density (Equation 1), we take the total number of Dealer and Pawnbroker licenses in county i in year t and divide it by county i's land area (100s of square miles).

$$GD_{i,t} = \frac{(D_{i,t} + PW_{i,t})}{A_i} \tag{1}$$

[13]It would be prudent for a business focused on hunting expeditions, for example, to have an FFL in order to accept firearm transfers by mail, sell small volumes of firearms and equipment, and provide gunsmithing services.

where $D_{i,t}$ and $PW_{i,t}$ are the number of Dealer and Pawnbroker licenses issued, and A_i is the county's area in square miles (100s).

This naive measure of gun density ignores two qualities of firearms: namely, firearms are durable and expensive. These two qualities suggest individuals will shop around for a firearm and not limit their purchase to stores within their county's borders. Instead, gun buyers might travel to a neighboring county to purchase a firearm that is on sale or seek out a used gun in the nearby geographic area. Consequently, the area of interest may not only be the gun density in county i in a particular year, but also the gun density in county i *and* the gun density in the counties surrounding county i:

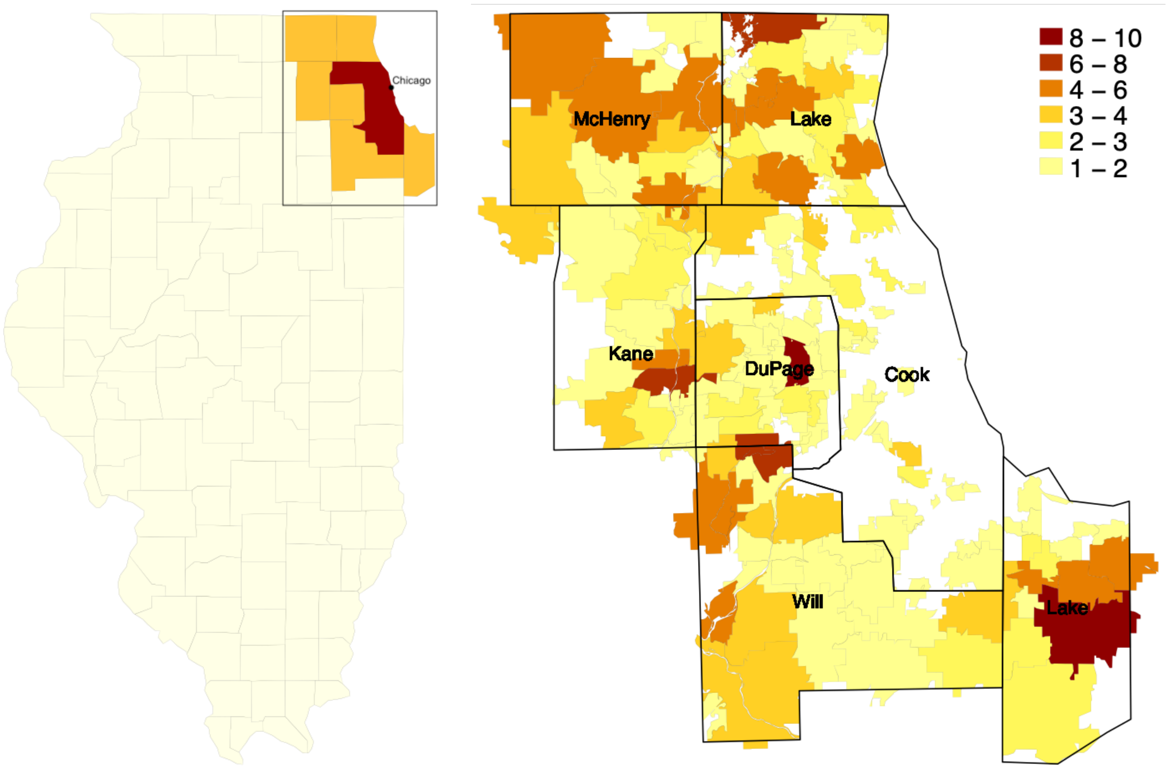
$$GD_{i,t} = \frac{\Big(D_{i,t} + PW_{i,t} + \sum_{j=1}^{n}(D_{j,t} + PW_{j,t})\Big)}{A_i + \sum_{j=1}^{n}(A_j)} \tag{2}$$

where $D_{i,t}$ and $PW_{i,t}$ are the number of Dealer and Pawnbroker licenses issued in county i in year t, $\sum_{j=1}^{n}(D_{j,t}+PW_{j,t})$ is the total number of Dealer and Pawnbroker licenses issued in the j counties surrounding county i in year t, A_i is the county's area in square miles (100s) and $\sum_{j=1}^{n}(A_j)$ is the total land area in the counties surrounding county i. We refer to this as the *halo* of county i.

To get a better understanding of the halo measure, consider an individual who wishes to purchase a firearm and lives in Cook County, Illinois (home of the city of Chicago and represented by the darkest region in Figure 2 on the left). The right side of Figure 2 shows the heat map of the number of FFLs at the zip-code-level across Cook County and the counties sharing a border with Cook County. While it may seem as though this individual would have a difficult time locating a firearm for purchase in Cook County due to lack of gun dealers, she is only a short distance away from some the country's most gun-dealer-dense zip codes (many above the 90th percentile) in neighboring counties, like DuPage County. Consequently, one could reasonably assume that there is a halo of counties around her home county that she would be willing to travel to purchase a firearm (i.e., the shaded counties surrounding Cook County on the left of Figure 2). It is also reasonable to assume that the significant amount of traditional gun market activity just outside of Cook County will spill over into Cook County through secondary gun markets (i.e., private sales, trades, and illicit activity). It is worth noting here that while Chicago's strict gun laws appear to work in terms of limiting traditional gun markets in the city itself, it is clear that these traditional gun markets can simply locate just outside of the jurisdiction of those laws, which creates the opportunity for secondary markets as well. Additionally, we allow for halos to cross state lines for adjacent counties, as shown by the inclusion of Lake County, Indiana in the Cook County halo. Although federal law prevents residents from one state from purchasing handguns in a different state through FFLs, most state laws still allow long gun purchases in traditional markets, and secondary markets are not necessarily limited in this way.

Figure 3 presents the practical effect of using a halo measure of gun density and not a county-level at a national view. Essentially, looking at the halo gun density smooths out the "topography" of firearms in an area. This is a reasonable adjustment not only for the reasons discussed earlier, but also prevents under-counting of firearms in a location (e.g., local ordinances preventing gun dealers from setting up shop within a city/county and small populations). Put differently, a coarser measure of gun density works to reduce measurement

Figure 2: Example of a Halo of Counties



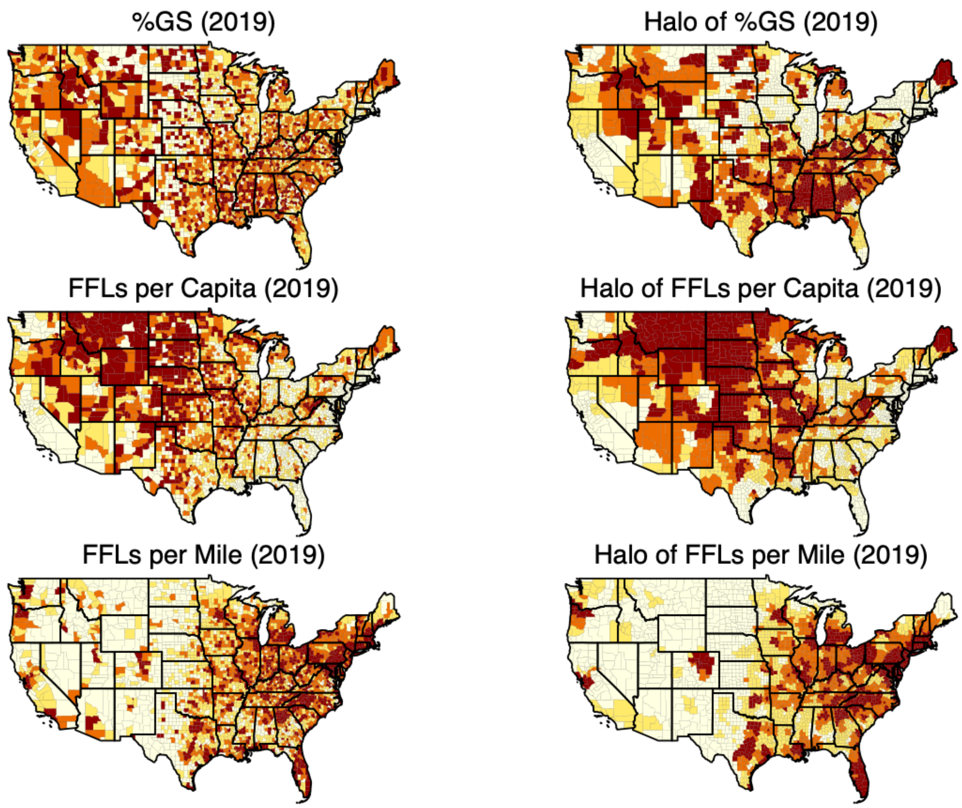
Notes: Halo county example for Cook County, IL. On the figure on the right, the dark shaded county represents the county where the gun buyer lives, lightly shaded counties represent counties that the buyer may be willing to drive to in order to purchase a gun (halo). The figure on the right show the detail of the halo of Cook County with zip code level FFLs shown by the heat map. Despite not many guns being available (as measured by FFLs) in Cook County, there is significant gun density in the surrounding counties. White space indicates zero.

error. Figure 3 also visually demonstrates the primary reason we prefer using FFLs per mile as a measure of gun density, as opposed to the percent of suicides committed with a gun or FFLs per capita. The percent of suicides committed with a gun, when examined at the county level appears to be the highest in rural areas (due to the previously discussed confounding demographic factors associated with the gun suicide ratio), which suggests it is not picking up the variation in gun availability that would explain the occurrence of homicides. FFLs per capita (as well as almost any per capita measure) tends to have the same problem and even more heavily favors rural areas, especially those with a lot of hunting and wilderness tourism (e.g., such as Idaho, Wyoming, and Montana), and completely misses all large population centers.[14]

Using FFLs per 100 square miles in the halo region (our preferred measure) shifts gun availability back toward population centers, but not exclusively so (notice the high concentration of gun density in the southeast and midwest regions). For example, the two

[14] This is likely due to a relatively large number of outfitters and hunting guides who have an FFL in order to be able to accept firearms transfers through the mail.

Figure 3: Gun Density by Individual Counties (Left) & By County Halo (Right)

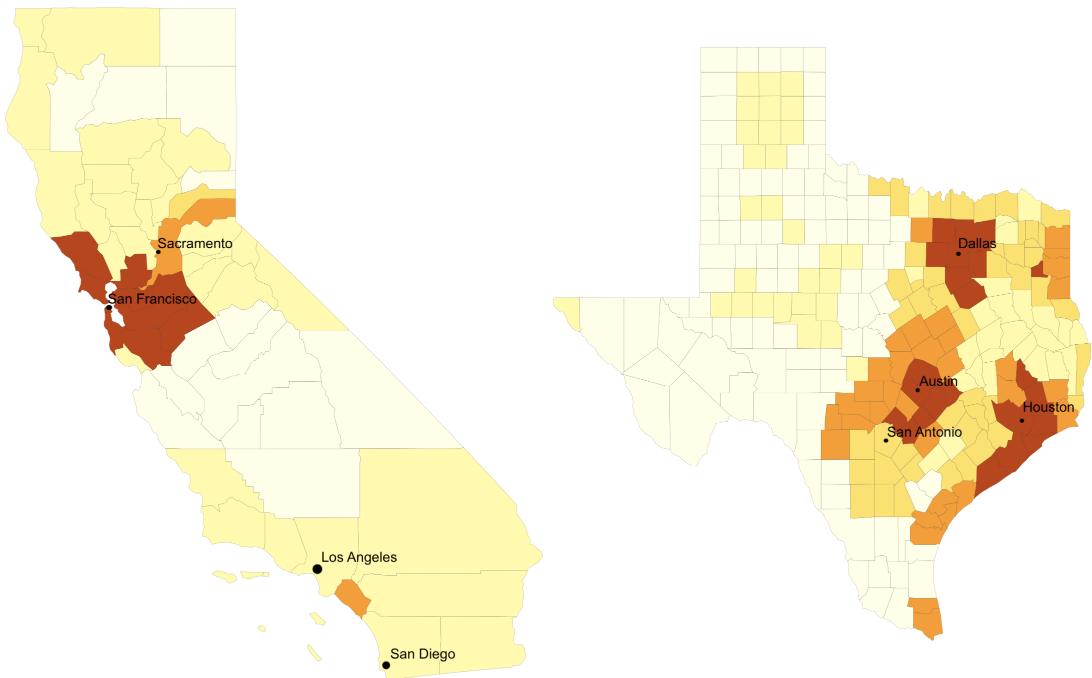


Notes: Gun density by competing measures: percent gun suicides (%GS), Federal Firearm Licenses per 1,000 residents (FFLs Per Capita), and Federal Firearm Licenses per 100 miles (FFLs per Mile), which is our preferred measure.

other gun availability measures (% GS and FFLs per capita) indicate the regions around Chicago, Los Angeles, New York, and Detroit have a curious lack of firearm availability, while our FFLs per 100 square miles measure shows a high concentration of guns in these areas. Perhaps the most striking example is that of north-central Colorado, which contains cities infamous for mass shootings (Boulder, Aurora, Columbine, etc.). The percent of suicides committed with a gun and the per capita measure suggest this area has very low gun availability. On the contrary, our gun density measure suggests this area has the highest concentration of guns in the western United States.

Figure 4 shows in detail the significant amount of within-state variation in FFL density for two dramatically different states: Texas and California. Texas has relatively lax gun laws relative to California, and most people would assume that Texas has a lot more guns overall than California. It is true that parts of east Texas appear to have a high concentration of guns; however, in much of the state, the FFL density is in the lowest quintile nationally. Likewise, there are areas of north-central California—particularly around the Bay Area—in which FFL density is on par with east Texas. Notice again that FFL density does not merely mimic population density. Los Angeles County is the nation's most populous county,

Figure 4: Within State Variation in FFL Density (2003)



Notes: Darker regions represent a higher quintile of FFLs per square mile.

containing more than a quarter of the people living in California, yet it is only in the second quintile of FFL density.

FFLs, and therefore FFLs per 100 miles, also vary substantially across time. A graph of the total number of Dealer and Pawn Licenses in the United States is found in Figure 5. There is substantial geographic and inter-temporal variation in the number of FFLs. From 2003 to 2009 the number of FFLs dropped by about 10,000 and then increased steadily until 2018. Given the time and spatial variation, and correlation with existing measures of gun prevalence, we believe FFL density is a reasonable measure of gun prevalence.

3 Data and Methodology

Our analysis uses data from only the contiguous United States. In Section 4.1, we illustrate how our halo measure of gun prevalence is related to homicides as measured by death certificate data taken from the CDC Wonder database. We compare these results to those using the competing measures of gun prevalence. These are our main results. In Section 4.2, we perform a robustness check by estimating similar models as those found in Section 4.1—only

Figure 5: Changes in Dealer and Pawn Licenses

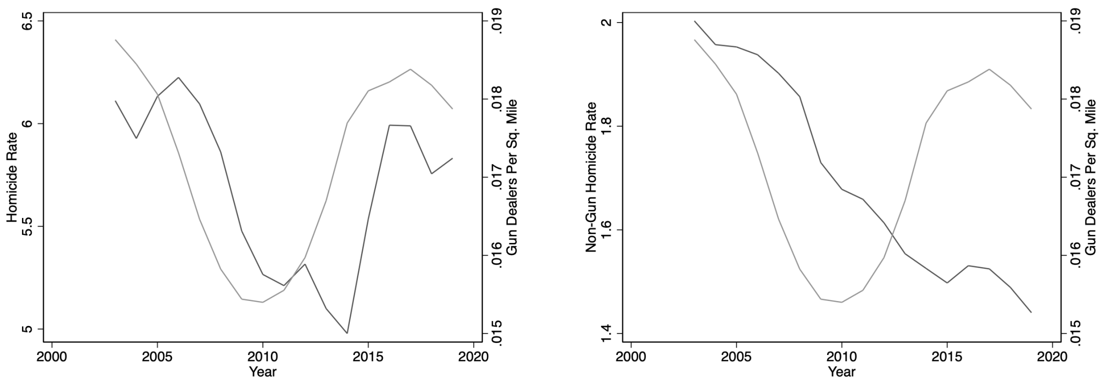
here we use the homicide counts from the FBI.[15] In Section 4.3 we explore the heterogeneous effect of gun dealer density using the original CDC data.

Mortality and demographic (e.g., county population, age, and racial demographics) data come from the CDC Wonder database. We primarily focus on CDC death certificate data rather than local law enforcement data from the Federal Bureau of Investigation (FBI) due to the FBI data being based on voluntarily reported crime counts, which under-counts the total number of homicides, and "accounting" problems which we discuss below. However, given that these data are commonly used in the literature on crime, it is worth exploring if our results change when using the law enforcement data.[16] We focus on two types of deaths: total homicides and non-gun-related homicides. Non-gun-related homicides serve as a kind of "placebo check" to test that our homicide results are not being spuriously driven by the

[15] A few notes about changes we made to the the data: i) to make the FBI and CDC data more comparable, we collapse the five boroughs of New York (Bronx, Brooklyn, Manhattan, Queens and Staten Island) into one "New York" county, ii) Broomfield county Colorado is combined with Boulder county, and the independent cities of Virginia are combined with their nearest neighbor. All county adjacencies were adjusted to account for these changes.

[16] Although we prefer the CDC homicide data, it is important to note that the CDC data is not without its problems. County death counts are based on the victim's county of residence rather than—and in contrast to the FBI data—where the death occurred, and these CDC data cannot inform any questions related to how gun prevalence can affect crime rates other than homicide.

Figure 6: Changes in Homicide Rates Relative to Gun Density



Notes: Yearly death rates (dark grey line) versus yearly gun dealers per 100 miles (light grey line).

kinds of homicides least affected by gun prevalence.[17] A graph of these death rates (per 100,000) across time is found in Figure 6. In each of these figures, we also include the number of gun dealers per 100 square miles (right-hand axis). Analogous figures for each state are found in Figures A1 and A2 found in the appendix.

To account for some of the socioeconomic and demographic differences between counties that may affect mortality rates, we use Census data on population, race, and gender composition and the median income from the Bureau of Labor Statistics (BLS). We do not combine rural counties into large rural county groups. We do so because, even in counties with small populations and in the same state, there is substantial heterogeneity in terms of demographics, gun dealers, and income. For instance, counties with the highest percent of Black residents are not urban counties but rural ones in the deep south (e.g., over 80 percent of residents in Jefferson County, Mississippi identify as Black). Summary statistics for the dependent and control variables are found in Table 2. Table 2 also includes the summary statistics of the number of federal firearms licenses issued to dealers and pawnbrokers (which make up nearly 90 percent of all FFL licenses in our data), the number of these FFLs per 100 square miles, and various other measures of gun density. Histograms for the deaths and explanatory variables are found in Figures A3 and A4 in the Appendix.

As a point of comparison, we contrast our results with another common measure of gun prevalence that is available at the local level: the proportion of gun suicides to total suicides. However, this introduces a complication, as there are many county-years with no reported suicides. In these cases, we replace the undefined proportion of gun suicides with 0. There are roughly 6,800 observations that are impacted by this replacement, which is roughly 350 counties per year.

Homicide is a count variable with a significant number of zeros. Consequently, we estimate Equation 3 using two methods: First, we transform the dependent variable using the inverse hyperbolic sine (IHS) of the homicide/non-gun homicide rate in county i in

[17]We note that gun prevalence could increase violent encounters such that non-gun-related homicides increase as well, which is why we focus on total homicides as our primary measure.

Table 2: Summary Statistics

	Mean	Std. Dev.	Min	Max
Ln Pop.	10.3	1.46	4.01	16.1
% Male	0.50	0.021	0.43	0.73
% Black	0.095	0.15	0	0.87
Ln Income	10.7	0.26	9.73	11.9
Homicides	5.73	28.2	0	1070
No-Gun Homicides	1.70	7.20	0	249
FFLs PC (H)	0.42	0.28	0.011	2.52
FFLs PC	0.53	0.51	0	16.4
FFLs PM(H)	2.90	2.36	0.082	22.5
FFLs PM	3.12	4.43	0	140.8
% GS (H)	0.58	0.14	0	1
% GS	0.53	0.34	0	1
Observations	52207			

Notes: Summary statistics of the main variables of interest. (H) indicates that the variable is a local area measure (e.g., Figure 2).

year t (Burbidge et al., 1988).[18] We estimate Equation 3 using a standard linear fixed effects regression. Because the IHS is not invariant to different scaling (see Aihounton and Henningsen, 2020), we also estimate Equation 3 with the count of homicides as the dependent variable using a fixed-effects poisson regression with cluster-robust standard errors to account for over-dispersion. The independent variables include a vector of county characteristics (natural log of the population, natural log of median income, percent male, and percent Black) in county i in year t, county-specific fixed effects, ψ, and county-specific time trends, which allows for heterogeneous time trends. Finally, we also include one of the six measures of county gun density—all of which are lagged two years. The coefficient on the logged population is constrained to one in all of the poisson regressions so that the coefficients are comparable across estimators.[19]

$$E[y_{i,t}|x] = \beta_0 + \beta_1 GD_{i,t-2} + \beta_j X + \psi_i + \psi_i * \tau \tag{3}$$

We lag the gun density measures for two reasons. First, lagging the measure reduces concerns about reverse causality (see Lang, 2016; Duggan, 2001; Cook and Ludwig, 2006; Moody and Marvell, 2005). Second, a new gun dealer will likely receive a FFL from the ATF some time before they begin selling to the public, as the FFL will be necessary to have inventory shipped to the point of sale. To this point, it is common in the ATF data to see a new FFL granted to a person and address with no business name associated with the license, but for a business name to be registered to the same individual and address upon renewal of the license, which suggests the FFL is often acquired some time before a

[18] The inverse hyperbolic sine transformation is used to avoid dropping county-years in which there are zero homicides and yields the same interpretation as a standard logged rate of the dependent variable.

[19] Estimates do not change if we instead add the natural log of population as a regressor with an unconstrained coefficient.

business opens to the public. Finally, a longer lag takes into account the time it takes for guns to move to people who are likely to commit crime or to actually be used in a crime once acquired. In 2019, roughly 10.7 million firearms were manufactured for non-military purposes in the United States.[20] While this implies that millions of new firearms will be in the hands of Americans, most of the weapons will, at least initially, belong to individuals who pass federally mandated background checks and who will not commit a crime.

This does not mean that guns will not drift toward individuals who are willing to commit crime. According to (Alper and Glaze, 2019), among prisoners (state and federal) who possessed a firearm during the offense that led to them serving time, only 10 percent obtained the weapon from a retail store. On the other hand, 25 percent obtained the weapon from an individual (e.g., friend/family member), 43 percent purchased the weapon through the black/gray market, and another 6 percent stole the weapon. What this means is that it takes time for a gun to move from a lawful owner to a criminal. Therefore, it is unrealistic to expect the existence of a new FFL to change the homicide rate in the first year of its existence. Critics of a two year lag might note that the average age of a firearm used to commit a crime is between 10–15 years old (Braga et al., 2020), but this statistic is somewhat misleading in this context as gun dealers regularly sell used guns.[21] However, all of the results that follow are robust to using 1 year or 3 year lags instead of 2 year lags. A plot of these different lags are found in Figure A5 along with the first, second, and third lead of gun dealer density.

One of the major threats to causally identifying the coefficients in Equation 3 is that a strong serial correlation in the outcome variable may result in an implicit relationship between our explanatory variables and the idiosyncratic error. As a way around this problem, we consider an alternative approach. Equation 4 is a dynamic first difference regression estimating the change in the death rate over year t and $t-1$ in county i using the change in the same vector of county controls, the change in the two-year lagged gun density measure, and the county-specific time trends.

$$E[\Delta y_{i,t}|\Delta x_i] = \beta_1 \Delta y_{i,t-1} + \beta_1 \Delta GD_{i,t-2} + \beta_j \Delta X_{i,t} \tag{4}$$

However, equation 4 might still suffer from endogeneity due a correlation between $\Delta y_{i,t-1}$ and the error. Therefore, instead of estimating equation 4, we take the standard Anderson-Hsiao approach and instrument $\Delta y_{i,t-1}$ with $y_{i,t-2}$. Estimates using this approach are found in Table A2 in the Appendix.

We cluster standard errors at the county level. Our main assumption in doing so is that the error terms across counties are uncorrelated—meaning that a change in the homicide rate in one county does not change the homicide rate in an adjacent county—except through a change in the number of FFLs in an adjacent county. That is, county homicides are assumed to only be related through a common gun market. Given that most crime occurs between neighbors, acquaintances, and family members, this is plausibly true.

[20] According to the ATF, 7,011,945 firearms were produced in the US, excluding production for the US military. Of those 314,482 were exported. An additional 3,986,663 were imported to the US. This represents an upper bound for the number of weapons introduced to the public, as this number includes weapons produced for law enforcement agencies.

[21] For example, one of the authors sold a 9mm Browning High Power that was roughly 20 years old to a local pawn shop when his twins were born.

4 Results

4.1 Homicides from CDC Wonder

Our first of set results are presented in Table 3. There are two panels—each showing a different way to estimate the effect of gun density on total homicides—and six columns in each panel—each showing a different measure of gun availability—for a total 12 sets of results. From top to bottom, the panels show coefficients for estimating the model via: i) linear fixed effects and ii) fixed effects poisson regression. Each column in the panels are labeled by the six gun density measures available at the county level. From left to right, they are the percentage of suicides involving a firearm (%GS), the number of FFLs per 1,000 people (FFLs PC), and the number of FFLs per 100 square miles (FFLs PM). The last three columns, designated with "(H)", indicate models using a gun prevalence measure calculated using the halo of counties surrounding county i. The halo measure of FFLs per 100 square miles, FFLs PM (H), is our preferred measure of gun prevalence. As all these estimators are log-linear, all coefficients are comparable and can be interpreted as semi-elasticities.

In general, the coefficient estimates are largely consistent for most measures of gun density across estimation methods. The percent of suicides committed with a gun—measured at both the county level and county halo level—has a small, negative, and statistically insignificant association with total homicides. This is unsurprising, as the measure likely better reflects specific demographic characteristics rather than gun prevalence, and will be heavily correlated with county trends.

Estimates using the number of FFLs per 1,000 people (FFL PC and FFL PC(H)) are very inconsistent across estimation methods. The estimates using the county measure and the halo measure are about 10 times larger when estimated via poisson regression rather than ordinary least squares. The instability of the coefficients across estimation methods suggests that any significant coefficients likely represent spurious correlations. The most likely explanation for this instability is that this measure—as well as any other gun measures relying on a per capita adjustment—largely picks up rural counties (see Section 2.2) with low homicide counts.

Our preferred measure of gun density, the halo of FFLs per 100 square miles (FFL PM(H)), shows a consistent magnitude and level of statistical significance across estimation methods. We see a one-unit change in FFLs per 100 square miles is associated with between a 2.1 to 4 percent increase in total homicides. We found virtually no difference in coefficients (or statistical significance) between the standard linear model and the Anderson-Hsiao dynamic model (0.021 vs. 0.023) which suggests that autocorrelation in the error is not biasing our results; thus, we placed these results in Appendix Table A2.[22]

When gun density is measured at the county level (FFL PM), rather than the county

[22] We also test for serial correlation by comparing coefficients for various leads and lags of gun density in our main specification (see top left panel of Figure A5). In general, our results are robust to between 1 to 3 lags of gun density, and the leads are gun density are small and insignificant, suggesting no serial correlation. We note the third lead on gun dealer density, FFLs PM(H), is statistically significant and negative. However, the third lead (see bottom left panel of Figure A5) is not statistically significant and smaller in magnitude, when using dynamic panel methods (Anderson-Hsiao). Given that the coefficient estimate on the 2 year lag of gun dealer density is .023 using the Anderson-Hsiao method and .021 using our standard linear model we conclude that accounting for any serial correlation would not change our main result.

Table 3: The Effect of Guns Density on Total Homicides (CDC)

	Linear Fixed Effects					
	%GS	FFL PC	FFL PM	%GS(H)	FFL PC(H)	FFL PM(H)
Gun Dens.	-0.0081	0.0045	0.0090***	-0.022	0.17***	0.021***
	(0.0075)	(0.011)	(0.0017)	(0.023)	(0.059)	(0.0038)
Ln Pop.	-0.48***	-0.42***	-0.39***	-0.48***	-0.34**	-0.34***
	(0.13)	(0.12)	(0.13)	(0.13)	(0.13)	(0.13)
% Male	0.27	-0.31	-0.33	0.32	-0.23	-0.34
	(0.90)	(0.89)	(0.89)	(0.90)	(0.88)	(0.89)
% Black	1.44	0.72	0.77	1.41	0.57	0.71
	(1.04)	(0.95)	(0.95)	(1.05)	(0.95)	(0.95)
Ln Income	0.22***	0.20***	0.19***	0.22***	0.19***	0.18***
	(0.039)	(0.038)	(0.039)	(0.039)	(0.038)	(0.039)
R^2	0.34	0.34	0.34	0.35	0.34	0.34
LL	-15712.7	-17008.0	-17001.5	-15665.3	-17001.0	-16998.7
Counties	3071	3071	3071	3071	3071	3071
Observations	46065	49136	49136	46025	49136	49136

	Fixed Effects Poisson					
	%GS	FFL PC	FFL PM	%GS(H)	FFL PC(H)	FFL PM(H)
Gun Dens.	-0.022	0.43***	0.021***	-0.054	1.39***	0.040***
	(0.019)	(0.092)	(0.0029)	(0.056)	(0.19)	(0.0095)
% Male	-3.11	-3.38	-1.71	-3.14	-1.70	-2.78
	(2.32)	(2.23)	(2.17)	(2.33)	(2.21)	(2.06)
% Black	4.06***	4.36***	4.84***	4.06***	4.93***	4.26***
	(1.32)	(1.04)	(1.19)	(1.32)	(1.06)	(0.92)
Ln Income	0.71***	0.64***	0.54***	0.71***	0.58***	0.55***
	(0.091)	(0.077)	(0.076)	(0.091)	(0.075)	(0.076)
Pse. R^2	0.89	0.89	0.89	0.89	0.89	0.89
LL	-62496.1	-66840.3	-66745.6	-62487.7	-66779.6	-66771.7
Counties	2900	2908	2908	2899	2908	2908
Observations	43500	46528	46528	43470	46528	46528

Notes: Each column corresponds to a different measure of gun density. From left to right: percent of gun suicides as a share of total suicides, FFLs per 1000 county residents, FFLs per 100 square miles, percent of gun suicides in the local area over the total suicides in the local area (halo), FFLs in the local area per 1,000 local area residents (halo), and FFLs in the local area per 1,00 square miles (halo). Top panel estimated with linear fixed effects regression, and bottom panel estimated with fixed effect Poisson. Dependent variable is the inverse hyperbolic sine of the homicide rate in the top panel. Poisson estimates use homicides counts. All models include county-specific linear time trends and county fixed effects and have standard errors clustered at the county level. Stars correspond to statistical significance: *** $p < 0.01$, ** $p < 0.05$, and *$p < 0.1$.

halo, the coefficients are about half as large. These estimates suggest that a one-unit change in FFLs per 100 square miles is associated with a 0.9 to 2.1 percent increase in homicides. Though it is not entirely clear what is causing the attenuation of these estimates relative to the halo estimates, it is consistent with our concerns about measurement error discussed in Section 2.2. Many counties are relatively small, and individuals in many places are likely prone to buying goods (particularly expensive, durable goods, like firearms) across county lines.[23] Thus, our halo measure of gun density is more likely to represent the relevant purchasing area for the average consumer.

To contextualize our main result, a one-unit change in FFLs per 100 square miles is

[23] Likelihood to purchase a firearm from a dealer outside one's county is also likely determined by local gun dealer ordinances.

very large—more than a 40 percent increase from the median value. This translates into approximately 5.3 additional gun dealers in the median county. In 2019, each gun dealer was responsible for over 180 background check inquiries for handgun and long gun purchases to the FBI. While every background check does not result in a purchase, we can make some assumptions to approximate the number of additional guns per dealer per year. If we assume the number of new firearms in the US is approximately equal to the total number of manufactured firearms plus imported firearms minus exported firearms, then there are approximately 93 new guns for every 100 background checks for potential handgun and long gun purchases. Thus, if a new FFL dealer in a county behaves according to the national average FFL dealer, then a one-unit change in FFLs per 100 square miles corresponds to an increase of about 887 guns per county per year. Despite the crude nature of this calculation, it is safe to say that an increase of one FFL dealer per 100 square miles would result in hundreds of new firearms circulating in that county.

In contrast, a 2.1 percent increase in homicides is quite small—the median county has only 1 homicide per year. For the entire United States, a 2 percent increase would translate to approximately 400 additional homicides per year. While this may seem high, the equivalent increase in FFL dealers to generate that change (in 2019) would be nearly 26,000. Using the same back-of-the-envelope calculations as above, this would translate to about 4.3 million new guns per year or just under 11,000 guns per homicide.

Estimates for the relationship between our measures of gun density and non-gun homicides are found in Table 4 and are arranged identically to Table 3. Point estimates for our preferred gun density measure, FFL PM(H), are an order of magnitude smaller than the total homicide estimates and statistically insignificant. Estimates using the Anderson-Hsiao approach are found in Table A3 in the Appendix.[24] Other measures of gun prevalence also appear statistically unrelated to non-gun homicide. Tables 3 and 4 taken together show that when our preferred measure of gun density, FFLs PM (H), increases we see a small increase in the total homicide rate, but we see no discernible effect on the non-gun homicide rate. This suggests two points: i) the geographic gun density measures are not measuring an unobserved local propensity to murder or underlying trend in homicides and ii) it shows that reductions in geographic gun density is not causing individuals to substitute into other methods of murder.[25]

As an additional robustness check, we investigate whether our results are driven by local economic changes. Gun dealers are businesses, and fluctuations in economic conditions can be correlated with many unobserved variables. To test this, we replace our gun density measure with a measure of business density—the number of business establishment per 100 square miles in the county and surrounding county halo—and estimate the same models found in Tables 3 and 4. These estimates are found in Appendix Table A5. They show no notable correlation between a change in business establishments and homicides or non-gun

[24] The estimate for FFLs PM appears marginally significant in using the Anderson-Hsiao estimator (see Appendix Table A3), but the effect size is about half of that observed when the dependent variable is the total homicide rate.

[25] Figure A5 also demonstrates that this non-result is not due to the chosen lag/lead of FFLs PM. Using both the standard fixed effects approach (top middle) and dynamic panel approach (bottom middle) we find the effect of various lags/leads of FFLs PM on non-gun homicides are minuscule and not statistically significant.

Table 4: Guns Density and Non-Gun-Related Homicides

	Linear Fixed Effects					
	%GS	FFL PC	FFL PM	%GS(H)	FFL PC(H)	FFL PM(H)
Gun Dens.	-0.0071	-0.0089	0.0026*	-0.015	0.015	0.0033
	(0.0050)	(0.0089)	(0.0015)	(0.017)	(0.040)	(0.0024)
Ln Pop.	-0.12	-0.071	-0.053	-0.12	-0.054	-0.050
	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
% Male	0.41	0.14	0.14	0.39	0.15	0.14
	(0.58)	(0.56)	(0.56)	(0.58)	(0.56)	(0.56)
% Black	0.76	0.31	0.33	0.74	0.30	0.31
	(0.71)	(0.67)	(0.67)	(0.71)	(0.67)	(0.67)
Ln Income	0.081***	0.078***	0.074***	0.081***	0.077***	0.074***
	(0.027)	(0.026)	(0.027)	(0.027)	(0.027)	(0.027)
R^2	0.12	0.12	0.12	0.11	0.12	0.12
LL	2010.9	1698.0	1698.5	2014.4	1697.5	1697.9
Counties	3071	3071	3071	3071	3071	3071
Observations	46065	49136	49136	46025	49136	49136
	Fixed Effects Poisson					
	%GS	FFL PC	FFL PM	%GS(H)	FFL PC(H)	FFL PM(H)
Gun Dens.	-0.033	-0.24*	0.0054	-0.093	-0.50**	0.00082
	(0.030)	(0.13)	(0.0033)	(0.084)	(0.21)	(0.0083)
% Male	3.32	2.31	2.86	3.25	2.01	2.63
	(3.16)	(2.96)	(3.02)	(3.16)	(2.95)	(3.00)
% Black	1.45	0.14	0.77	1.43	-0.074	0.40
	(2.13)	(1.80)	(1.95)	(2.13)	(1.76)	(1.83)
Ln Income	0.26***	0.33***	0.29***	0.26***	0.35***	0.31***
	(0.082)	(0.074)	(0.077)	(0.082)	(0.074)	(0.078)
Pse. R^2	0.74	0.74	0.74	0.74	0.74	0.74
LL	-40942.3	-44007.6	-44009.1	-40935.9	-44006.5	-44009.6
Counties	2716	2731	2731	2716	2731	2731
Observations	40740	43696	43696	40727	43696	43696

Notes: Each column corresponds to a different measure of gun density. From left to right: percent of gun suicides as a share of total suicides, FFLs per 1000 county residents, FFLs per 100 square miles, percent of gun suicides in the local area over the total suicides in the local area (halo), FFLs in the local area per 1,000 local area residents (halo), and FFLs in the local area per 1,00 square miles (halo). Top panel estimated with linear fixed effects regression, and bottom panel estimated with fixed effect Poisson. Dependent variable is the inverse hyperbolic sine of the homicide rate in the top panel, and Poisson estimates use homicides counts. All models include county-specific linear time trends and county fixed effects and have standard errors clustered at the county level. Stars correspond to statistical significance: *** $p < 0.01$, ** $p < 0.05$, and *$p < 0.1$.

homicides.[26]

4.2 Results for Homicides from FBI

As a robustness check, we now explore how estimates using CDC data compare to estimates using FBI data. Summary statistics for the new variables of interest are found in Table 5. Crime data comes from the FBI Crime Data API.[27] This data is reported by local law enforcement agencies using the Summary Reporting System (SRS), or the National

[26] Estimates for the poisson models are statistically significant; however, they are several orders of magnitude smaller and in the opposite direction (negative correlation) than our gun density estimates.

[27] Available online at https://crime-data-explorer.app.cloud.gov/api (last accessed August 1, 2021).

Incident Based Reporting System (NIBRS), and was accessed using the FBI's public API. County crime rates are identified using Originating Agency Identifier (ORI) of the reporting agency, which is matched to a county using the 2012 Law Enforcement Agency Crosswalk. As previously discussed, the crime data is of lower quality than the CDC data for two main reasons: i) law enforcement agencies voluntarily report their crime data, and ii) the location of the crime is based on the address of the law enforcement agency reporting, which could lead to accounting issues for agencies covering large areas (e.g., state-wide or multiple counties). These two bugs lead to an inconsistent number of law enforcement agencies reporting each year within in a given county. We are not the first to highlight these types of problems (c.f., Maltz and Targonski, 2002) and emphasize that results discussed using the FBI data should be taken only as a robustness check of our main result discussed in the previous section.

Table 5: Summary Statistics (FBI)

	Mean	Std. Dev.	Min	Max
Homicides (FBI)	5.07	27.0	0	1069
% of LEAs Rep.	0.79	0.26	0	1
Officers Per Capita	1.91	1.54	0	51.4
Observations	52088			

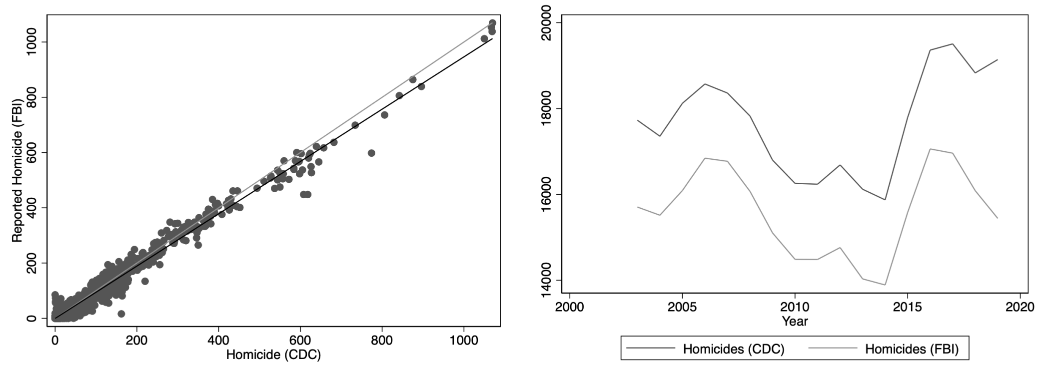
Notes: Summary statistics from 2003-2019. All variables come from the FBI and are based off of voluntary reports from local law enforcement agencies.

Despite potential problems, the county-collapsed local law enforcement homicide data is very similar to the CDC homicide counts. The overall correlation between the *county* homicide counts from 2003 to 2019 collected by the CDC and its FBI's counterpart is 0.991. To give an idea of how similar the two data sources are, a scatter plot depicting the correlation between the CDC's homicide count against the FBI's along with a 45° line (gray) and a simple estimated linear regression (black) is presented in Figure 7 (left panel). Overall 1,933 county years are missing over the 17 year FBI panel or roughly 113 counties per year. Many of these missing observations are likely zeros. Of the 1,933 observations missing in the FBI data, 1,264 had no reported homicides by the CDC. We also present the number of the number of homicides by year, measured by the CDC and FBI, in the right-hand panel of Figure 7. Overall, they match up fairly well but, in the more recent years, there is a dramatic drop in homicides reported by the FBI. This drop is not present in the CDC data.

Table 7 contains estimates of the effect of gun density on homicide using the homicide rate as measured by FBI. Table 7 is identical to Tables 3 and 4, containing 12 regression results varying by the measure of gun density and estimator (linear fixed effects and fixed effects poisson). The primary difference between these estimates and those presented in the previous section is that we include variables that control for the number of police officers per capita (Off. Per Cap), the percent of the agencies that report to the FBI (% Report), and the interaction of the percent of the agencies that report and the natural log of the county's population (% Rep. X Ln Pop).

The relationship between gun dealer density and homicides using FBI data is similar to that found when using CDC data; however, the estimated coefficients are slightly smaller

Figure 7: FBI and CDC Homicide Counts



Notes: (Left) Scatter plot of county homicides measured by the Centers of Disease Control from 2003 to 2019 versus the number of reported homicides by local law enforcement agencies collapsed to the county-level. Gray line indicates the 45 degree line (or 1 to 1 matching); black line is the fitted regression line. (Right) Total number of homicides in the United States from 2003 - 2019 from the FBI (black Line) and CDC (gray line).

across all estimation methods. For our preferred gun density measure, FFL PM(H), a one-unit increase in FFLs per 100 square miles is associated with a 1.6 percent increase in the homicide rate (3.1 percent when using the poisson estimator). This could be due to attenuation bias from the known measurement error in the FBI data, but the ultimate source of the difference in magnitude is unclear.[28] Like the results presented in Table 3, the coefficients on %GS and %GS(H) are in the opposite direction than we would expect. Point estimates from the Anderson-Hsaio estimation are, again, nearly identical in magnitude and significance to the point estimates from the linear fixed effects estimation, suggesting serial correlation is not biasing these results.[29] Those estimates can be found in Appendix Table A4.[30]

[28] We note that the difference in magnitude is not due to the inclusion of the additional regressors, police officers per capita and number of reporting agencies. The coefficients are nearly identical when these variables are removed from the regressions.

[29] Figure A5 demonstrates some evidence of measurement error in the FBI data. When using a fixed effects approach the third lead of FFLs PM (H) is statistically significant and negative and when using the dynamic panel approach the first and third lead are negative and significant.

[30] As a robustness check, we explore the relationship between gun dealer density and Aggravated Assault and Murders involving a gun (see Kaplan, 2021). There are three dependent variables we consider: the inverse hyperbolic sine of the Aggravated Assault (involving a gun) rate, the percent of all Aggravated Assaults involving a gun, and the percent of homicides committed with a gun (CDC). Using both linear fixed effects models and the Anderson–Hsaio specifications, we find increases in gun dealer density, FFL PM (H), is positively associated with all dependent variables. These results are found in Table A6. Because of issues with respect to FBI data quality, these estimates should be treated as only a test of the assumption that an increase in FFLs leads to an increase in the number of guns in a community. Yet, as a second robustness check (Table A7), we present identical models estimating the Aggravated Assault (involving a gun) rate and the percent of all Aggravated Assault involving a gun using only date from Law Enforcement Agencies (LEAs) that submitted data for more than 6 months in each of the 17 years in the panel. The statistical significance and magnitude of the coefficient on gun density increases in all four. We thank Tom Scott for this suggestion.

Table 6: Guns Density and FBI-Measured Homicide Rates

	Linear Fixed Effects					
	%GS	FFL PC	FFL PM	%GS(H)	FFL PC(H)	FFL PM(H)
Gun Dens.	-0.017**	-0.015	0.0050**	-0.036	0.039	0.016***
	(0.0074)	(0.023)	(0.0021)	(0.023)	(0.057)	(0.0038)
Ln Pop.	-0.29**	-0.25*	-0.21	-0.29**	-0.21	-0.16
	(0.14)	(0.13)	(0.13)	(0.14)	(0.14)	(0.14)
% Male	1.38	0.82	0.79	1.41*	0.83	0.76
	(0.84)	(0.77)	(0.77)	(0.85)	(0.77)	(0.78)
% Black	1.51	1.04	1.08	1.53	1.01	1.05
	(0.97)	(0.86)	(0.86)	(0.97)	(0.86)	(0.86)
Ln Income	0.071**	0.078**	0.068*	0.070*	0.074**	0.053
	(0.036)	(0.035)	(0.035)	(0.036)	(0.035)	(0.036)
Officers Per Capita	1.07	3.24	4.07	0.95	3.89	5.20
	(6.69)	(6.50)	(6.52)	(6.69)	(6.56)	(6.52)
% Reporting	0.27*	0.32**	0.31**	0.28*	0.32**	0.30**
	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)
% Rep. X Ln(Pop)	-0.013	-0.018	-0.018	-0.014	-0.018	-0.016
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
R^2	0.39	0.39	0.39	0.39	0.39	0.39
LL	-5968.3	-6646.7	-6644.1	-5972.4	-6646.7	-6639.3
Counties	2760	2764	2764	2760	2764	2764
Observations	39402	42106	42106	39390	42106	42106
	Fixed Effects Poisson					
	%GS	FFL PC	FFL PM	%GS(H)	FFL PC(H)	FFL PM(H)
Gun Dens.	-0.053*	0.34**	0.018***	-0.089	1.13***	0.031***
	(0.028)	(0.14)	(0.0038)	(0.078)	(0.26)	(0.011)
% Male	5.44	5.31	7.87*	5.44	7.01	6.34
	(4.91)	(4.23)	(4.34)	(4.90)	(4.28)	(4.18)
% Black	-0.50	0.74	1.23	-0.47	1.24	0.53
	(4.59)	(3.52)	(3.84)	(4.58)	(3.68)	(3.56)
Ln Income	0.62***	0.61***	0.51***	0.62***	0.55***	0.53***
	(0.11)	(0.092)	(0.091)	(0.11)	(0.088)	(0.089)
Officers Per Capita	-41.1***	-36.2**	-26.3*	-41.4***	-26.9*	-31.6**
	(15.9)	(15.1)	(14.6)	(15.9)	(14.4)	(15.2)
% Reporting	2.15***	2.16***	2.08***	2.15***	2.15***	1.90***
	(0.38)	(0.39)	(0.43)	(0.38)	(0.40)	(0.46)
% Rep. X Ln(Pop)	-0.15***	-0.15***	-0.15***	-0.15***	-0.15***	-0.13***
	(0.031)	(0.032)	(0.035)	(0.030)	(0.032)	(0.038)
Pse. R^2	0.89	0.89	0.89	0.89	0.89	0.89
LL	-53131.9	-56832.1	-56766.0	-53132.2	-56799.4	-56793.7
Counties	2474	2484	2484	2474	2484	2484
Observations	35961	38511	38511	35952	38511	38511

Notes: Each column corresponds to a different measure of gun density. From left to right: percent of gun suicides as a share of total suicides, FFLs per 1000 county residents, FFLs per 100 square miles, percent of gun suicides in the local area over the total suicides in the local area (halo), FFLs in the local area per 1,000 local area residents (halo), and FFLs in the local area per 100 square miles (halo). Top panel estimated with linear fixed effects regression, and bottom panel estimated with fixed effect Poisson. Dependent variable is the inverse hyperbolic sine of the homicide rate in the top panel, and Poisson estimates use homicides counts. All models include county-specific linear time trends and county fixed effects and have standard errors clustered at the county level. Stars correspond to statistical significance: *** $p < 0.01$, ** $p < 0.05$, and *$p < 0.1$.

4.3 Gun Dealer Density with an Application to the "Ferguson Effect"

In Section 4.1 we demonstrated a one-unit increase in gun density increases the homicide rate by between 2.1 and 4 percent, which translates into a rather small effect of firearms on homicides overall. However, a small overall effect could be the result of averaging large effects in some communities with near zero effects in others. If this heterogeneity is unaccounted for, it would underestimate the effect of firearms in some areas and over-estimate the effect in others. Such differences could be due to the possibility that gun dealers specialize in the types of firearms preferred by the local population. Some firearms are easy to hide and consequently more useful in committing crime (e.g., handguns) others are probably less useful (e.g., bolt-action rifles) due to their more cumbersome nature. So if a gun dealer locates in an area that has a lot of interest in hunting, it is likely they will specialize long guns—which are less useful in committing crime—resulting in a weaker link between gun dealer density and homicide. On the other hand, dealers located near urban and suburban populations will have more customers interested in purchasing a gun for personal protection and will, thus, carry more handguns and small arms.

An interesting avenue for investigating the heterogeneity in the gun/homicide relationship is the so-called "Ferguson Effect". Beginning in 2014, there is a large, rapid increase in homicides that is particularly pronounced for urban areas and areas with a higher percentage of Black residents. The Ferguson Effect is a term coined by the chief of the St. Louis police to suggest that the spike in homicides and other violent crime was due to an increased hesitancy of police officers to enforce the law due to media and legal scrutiny after the shooting of Michael Brown in Ferguson, MO in 2014. Edwards and Rushin (2017) investigated this hypothesis and found that there is a small, but significant, increase in crime in cities in which the local police department received increased scrutiny from the US Department of Justice. However, Morgan and Pally (2016); Shjarback et al. (2017) find very little evidence of changing police behavior after Ferguson; however, each only investigates a narrow area and time window. Interestingly, Desmond et al. (2016) finds that one of the effects of high-profile cases of police violence against Black individuals is an increased hesitancy to call the police in Black neighborhoods. This suggests that crime may be under-reported. However, one type of criminal activity is unlikely to be under-reported: homicides.

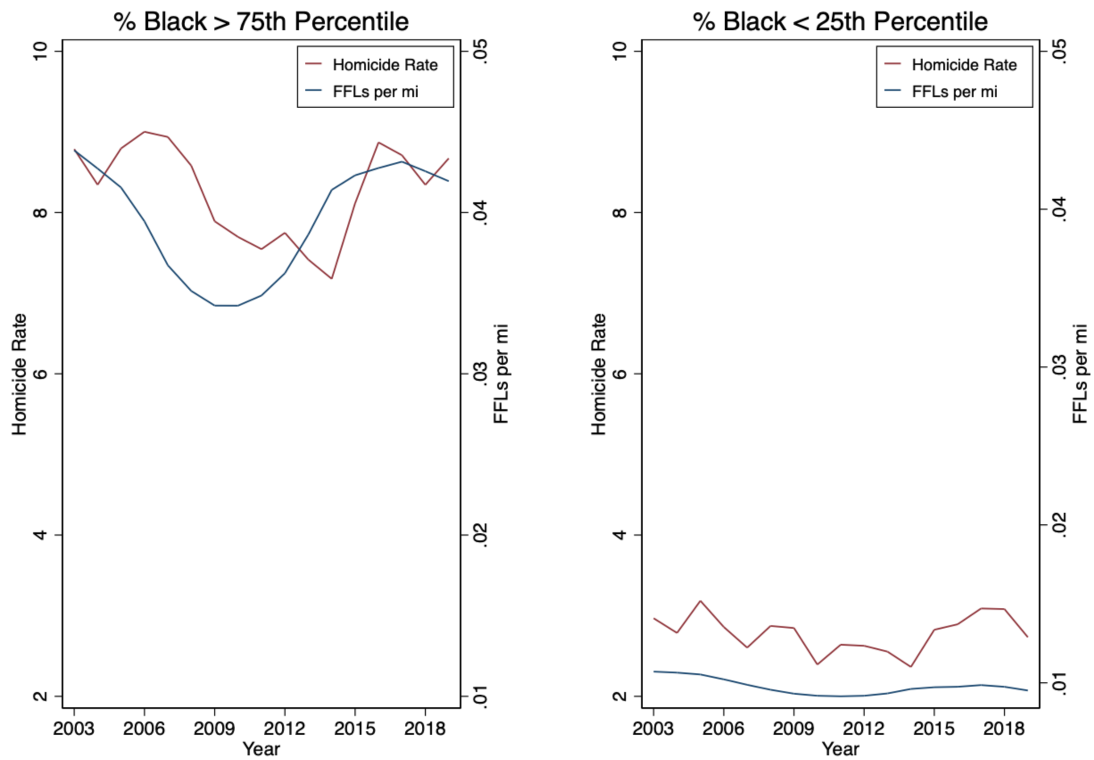
The right side of Figure 8 shows that homicide rates, indeed, rise quickly and remain high in counties with a high percentage of Black residents after 2014.[31] While this could be due to increased hesitancy among police to make arrests or a decreased willingness to call police among individuals in these counties, we offer a third possible explanation: an increase in the availability of guns in Black communities. In counties in the highest quartile of Black residents, the number of FFLs per 100 square miles—our gun density measure—falls steadily from 2003 to 2010, and that is followed by a declining homicide rate from 2006 to 2014. In 2011, gun density began to sharply increase in predominantly Black counties, with roughly 800 gun dealers added in these areas. This is followed by a sharp increase in homicides beginning in 2015. Although these are unconditional time series plots, a strong relationship between gun density an homicides is apparent. No such clear relationship can be seen in counties with in the lowest quartile of Black residents (left side of Figure 8), where there is comparatively almost no variation in gun density and, perhaps consequently, far less variation in homicide.[32]

We explore the heterogeneity in the effect of gun dealer density on homicide more formally by interacting gun dealer density with several county characteristics of interest. These results are presented in column 3 of Table 7 ("Interactions" under the "Homicide"

[31] We note that there is also an increase in homicides in counties with a low percentage of Black residents (left side of Figure 8); however, the increase is much smaller, far more gradual (happening over a 4 year period), and sharply falls by 2019.

[32] It is important to note that no such relationship can be identified if gun prevalence is measured by the ratio of gun suicides to total suicides. A figure similar to Figure 8 is presented in the Appendix in Figure A6, which uses the gun-suicide ratio rather than FFL density as the measure for gun prevalence. Given the lack of variation in the gun-suicide ratio in counties with a high percentage of Black residents, there is no discernible relationship present in the figure.

Figure 8: Relationship Between Guns & Homicide by Racial Composition



Notes: Total homicides and Gun Dealers in communities with the percent of Black residents in the top quartile (right) and communities with the percent of Black residents in the bottom quartile (left).

heading) the marginal effects are found in Figure 9. This model suggests that the negative consequences of gun dealers are primarily suffered in communities with a high percentage of Black residents, with gun dealers having almost no effect on homicides in counties with even the average percent of Black residents and increasing significantly as the percent of Black resident approaches the higher percentiles. The other characteristics investigated—percent male, median personal income, and population—have no significant effect on the gun dealer density-homicide relationship.

Given that the effect of gun dealer density on homicide seems to be most influenced by the percent of the county residents who are Black, we also obtain separate results for counties that are in the highest quartile of Black residents ($>$ 11 percent of the population) and for counties in the lowest quartile of Black residents ($<$ .9 percent of the population), on average over the 2003–2019 time period. These results are found in the first and second columns of Table 7. In predominantly Black communities, a one-unit increase in the number of gun dealers per 100 square miles results in a 3.4 percent increase in homicides in subsequent years—an effect more than 1.6 times larger than we found for the full sample. In contrast, estimates for the counties in the lowest quartile of Black residents are about a third of the size of our full sample and statistically insignificant. Our result echoes that of Williams (2017) who finds the repeal of Missouri's Permit to Purchase law, which required handgun

Table 7: Gun Dealer Density and County Characteristics

	Homicides			Non-Gun Homicides		
	% Black>75^{th}	% Black<25^{th}	Interactions	% Black>75^{th}	% Black<25^{th}	Interactions
% Male	-3.77*	-0.046	-0.47	-0.69	-0.31	0.023
	(-1.82)	(-0.04)	(-0.46)	(-0.50)	(-0.33)	(0.03)
% Black	1.93	-3.95	0.20	1.26	-2.57	0.17
	(1.54)	(-1.13)	(0.21)	(1.38)	(-1.14)	(0.26)
Ln. Income	0.30***	0.072	0.20***	0.074	0.100*	0.11***
	(3.62)	(0.94)	(3.71)	(1.39)	(1.70)	(2.84)
Ln. Pop	-0.47**	0.027	-0.33**	-0.23*	0.095	-0.044
	(-2.31)	(0.10)	(-2.51)	(-1.70)	(0.46)	(-0.43)
FFL PM (H)	0.034***	0.0080	0.020***	0.0078**	-0.0070	0.0055
	(6.16)	(0.49)	(2.60)	(2.39)	(-0.68)	(1.15)
FFL PM (H) X % Male			0.17			0.10
			(0.53)			(0.44)
FFL PM (H) X % Black			0.18***			0.045*
			(4.99)			(1.90)
FFL PM (H) X Ln Income			-0.0057			-0.012*
			(-0.60)			(-1.93)
FFL PM (H) X Ln. Pop.			-0.0019			-0.00015
			(-0.54)			(-0.07)
R^2	0.38	0.14	0.34	0.093	0.12	0.12
LL	-5046.8	-5730.8	-16984.8	5.53	-912.2	1701.4
Counties	769	851	3071	769	851	3071
Observations	12304	13616	49136	12304	13616	49136

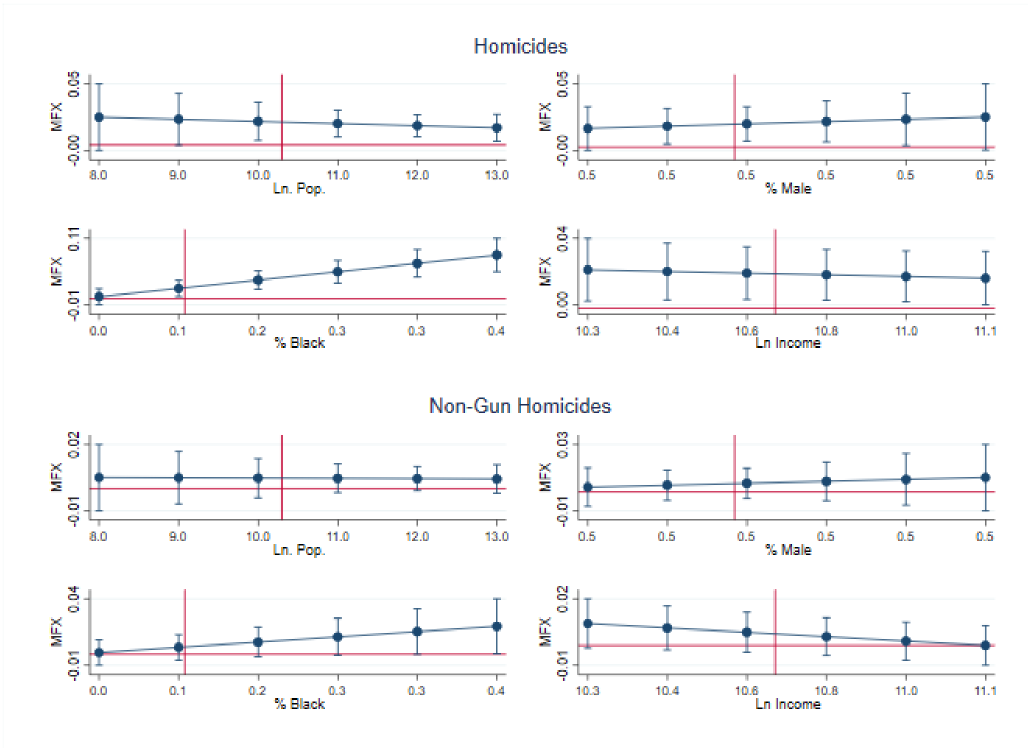
Notes: Estimated relationship between gun dealer density and Homicides (left three columns) and Non-Gun Homicides (right three columns). All models are linear fixed effects panel regressions and include county-specific linear time trends, county fixed effects, and have standard errors clustered at the county level. Columns one and four use the sample of counties that have a proportion of Black residents in the top quartile; columns two and five use the sample of counties in the bottom quartile. Columns three and six use the full sample but include the interaction of gun dealer density and county characteristics. Stars correspond to statistical significance: *** $p < 0.01$, ** $p < 0.05$, and *$p < 0.1$.

buyers to have a permit and submit to a background check, led to a significant increase in the African American homicide rate while having no effect on the white homicide rate. We emphasize, however, that we cannot say with certainty that increased gun density would have had no effect in communities with low Black populations, as the lack of effect in counties with low Black populations is likely driven by the fact that gun density remains relatively stable (low variance) in these counties during this time frame.

As in Table 4 we also explore the possibility that the relationship maybe spurious by estimating similar models but with the non-gun homicide rate as the dependent variable instead of the homicide rate. We find the effect of the interaction of gun dealer density and share of Black residents on non-gun homicides muted (4 times smaller) and marginally significant.

To investigate the difference in the variation of gun density and its subsequent effect on homicide, we use the business names listed in the FFL data to examine how the composition of gun dealers changes over time in different types of counties. We classify the license holders' business names into one of eight categories: Pawn, Outdoors, Defense, Big-box, Gun Smith, Patriotism, X-Guns, and Multiple Categories. Pawn indicates the FFL is a pawn-type license, Outdoors indicates business names containing a word indicating the store specializes in outdoor equipment, Defense indicates a business name containing a word indicating the store specializes in personal/home defense, Big-box indicates a business name containing a word indicating the business is a large chain store, Gunsmith indicates a business name that suggests the store is a gun repair shop, Patriot indicates a store name containing a "patriotic" word, X-Guns indicates a name containing a common name followed by guns/firearms, and Mixed Categories indicates a business name that could be

Figure 9: Marginal Effect of Gun Dealer Density



Notes: Estimated interaction effects. Top panel corresponds to model three in Table 7. Bottom panel corresponds to model six in Table 7. Error bars indicate 95% confidence intervals. Solid vertical line is the variable's mean.

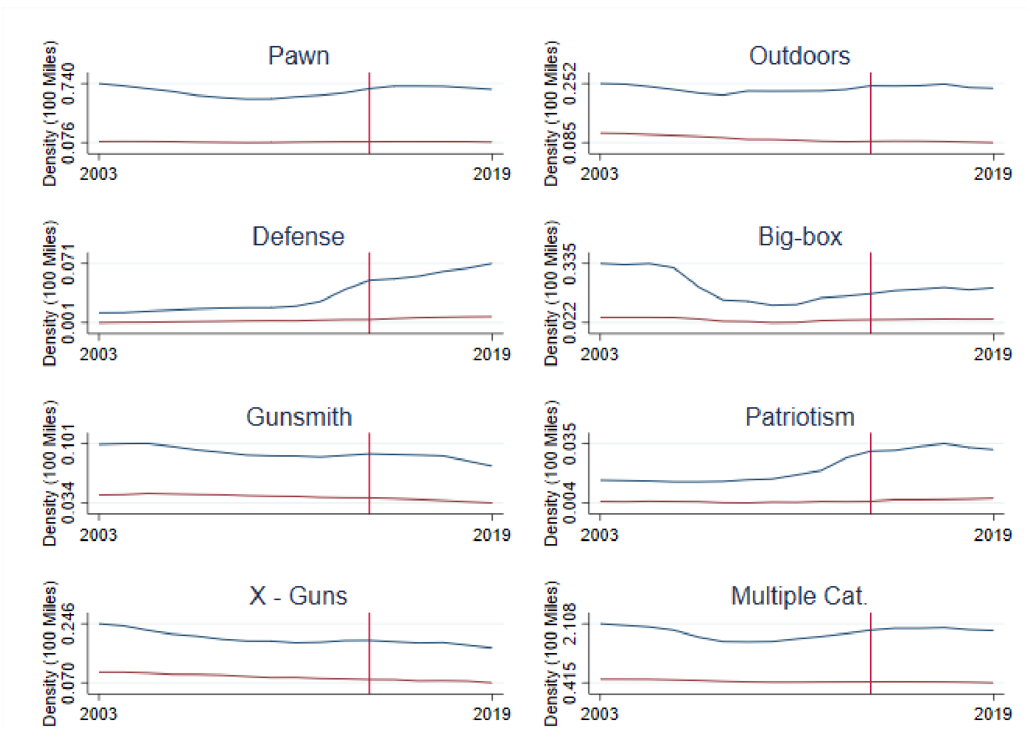
classified in more than one multiple. A full list of the words/names for each classification is found in the Appendix A.8. Our classification covers roughly 50 percent of FFLs with a business license. A breakdown of the share of gun dealers within each category by county type (i.e., top or bottom quartile in terms of percent Black residents) in 2016 is found in Figure A7 in the Appendix and suggests there is some heterogeneity in terms of the gun dealer types: namely, pawn type FFLs are noticeably more common in counties that have a large percent of Black residents.

This "snapshot" type analysis does not tell us anything about the relative density across types (i.e., FFL of classification X per 100 miles) and time—only the relative share within the county type in a specific year. To that end, we calculate a rough measure of gun dealer type density (Equation 5) by taking the total number of FFLs of classification z (e.g., Pawn, Outdoors, Defense...) county type b (e.g., % Black$\geq$11), in year t and dividing it by the total land area of counties of type b (which is 886,766 for counties with less than .9 percent of their residents identifying as Black and is 444,815 for counties with more 10 percent of their residents identifying as Black.)

$$GD_{z,b,t} = \frac{\sum_{j=1}^{n} FFL_{z,b,t}}{A_b} \tag{5}$$

In Figure 10 we illustrate how FFL density by business classification varies across time and location type. Three stylized facts emerge from Figure 10: First, dealer density, regardless of location type, is greater in counties with a higher percent of Black residents. Second, there seems to be little change in the density of dealer types in areas with a low percentage of Black residents, which is somewhat surprising considering the greater land area. Third, the decrease and subsequent increase in gun dealer density is not caused by one dealer type exiting the market and then reentering later. Rather, it seems that Big-box FFLs exited Black communities around 2007 only to be heavily replaced by Defense and Patriot type dealers beginning in 2011 and with sharp increases in 2014 and 2015. That is, there is a large decrease in corporate businesses selling guns in Black communities, and the homicide rate in these communities hits a trough a few years later. This loss of gun density is rapidly filled by an influx of dealers with names that suggest that they specialize in defense weapons, like handguns, in the years following Michael Brown's shooting. The decrease in the percentage of corporate retailers in these communities also may indicate an increase in the percentage of nearby dealers willing to bend or break federal gun laws.

Figure 10: Changes in Gun Dealer Density Type



Notes: Gun dealer density by classification type for counties in the top and bottom quartile in terms of percent of Black residents. Blue(red) line corresponds to counties in the top(bottom) quartile of percent Black. Vertical line corresponds to 2014, the year of Michael Brown's death.

The results presented above strongly suggest that a major factor contributing to the increase in violent crime in Black communities in the years after Michael Brown's death—the Ferguson Effect—is the differential increase in gun density in the short time before this event. To our knowledge, we are the first to demonstrate the potential role of gun availability in explaining this trend. Definitely separating other potential causes of Ferguson Effect from the "gun dealer effect" we identify here is outside the scope of the present work. However, the effectiveness of guns as a lethal instrument combined with the correlated fluctuation of gun density suggests that increases in gun density likely explain a significant portion of the increase in violent crime that has been identified as the Ferguson Effect. If this was not the case—and the effect was purely due to changes in police behavior or the willingness of citizens to contact the police—we would expect to see fluctuations in other crimes. This is not the case. In Figure 11, we present various crime counts in counties with Black residents in top quartile (% Black residents greater than 11 %) and the same crime rates in counties with a percent of Black residents in the bottom quartile (% Black less than .9 %). Unlike homicides in the Black community, which as we saw in the Figure 8 ebbed and flowed with gun dealer density, changes in the crime counts look nothing like changes in the number of gun dealers and had no noticeable change (in terms of trend) post 2014.[33]

The only type of crime for which we see a major change in trend, homicides, is the one most likely to change when it becomes easier to obtain a gun. It seems likely, therefore, that the propensity to call the police is not the primary mechanism of increased homicides in these communities, but rather that the availability of guns increased, which gave people an increased ability to commit homicide. Since guns are not as differentially useful in committing other types of crime, the trend of other crime rates did not change much.[34]

As a final point in support of guns being a primary cause of the increase in homicides and not a change in the propensity of Black Americans to call the police, we present some basic time trends in victimization reported by the National Crime Victimization Survey (NCVS).[35] The central idea here is that if the drop in crime was due to a decrease in the willingness of Black Americans to call the police (or report crime) and crime was actually increasing in these communities, we should see crime victimization rates found using survey methods in the Black Community increase.[36] A similar argument could be made for a decreased willingness of police to enforce the law. Instead, what we find is that, in general, crime victimization rates are falling or staying the same. This is shown in Figure 12. It is, however, important to note that, unlike crime rates, the survey results are not separated by Black and White communities but rather reported crime by Black and White Americans.[37]

[33] With the very minor exception of aggravated assault which is hardly surprising considering a firearm would not be an uncommon piece of capital equipment to be brandish (or used) in the commission of this type of crime.

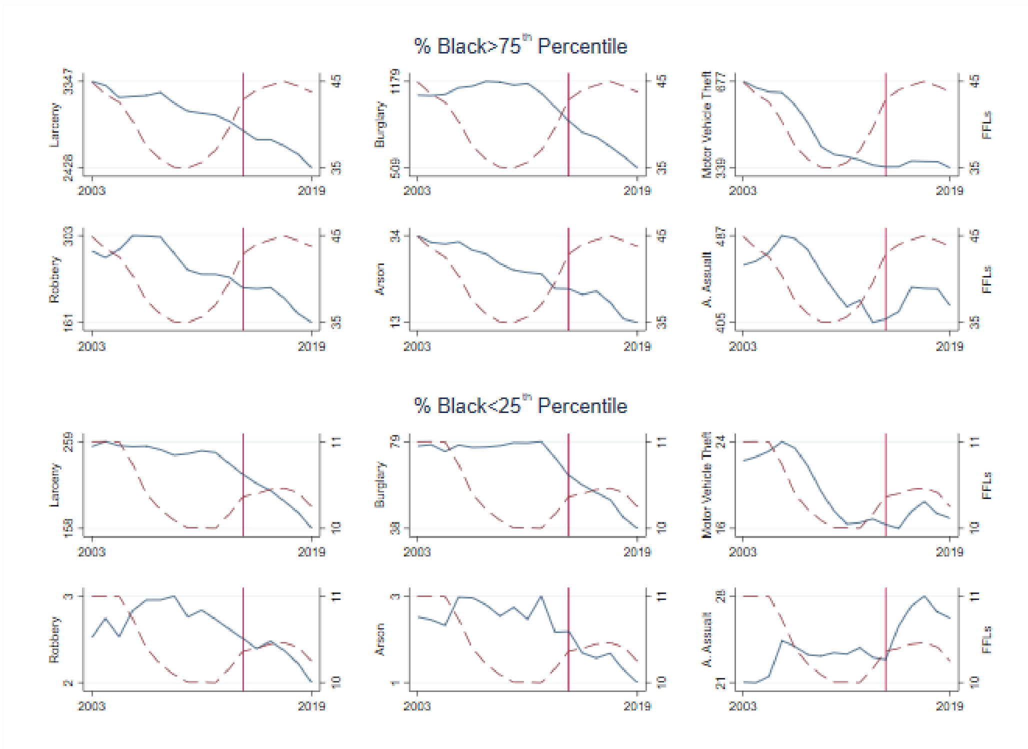
[34] In Table A8 in the Appendix we report the p-values for a series of known structural break tests using the crime data that has been collapsed by county type (top and bottom quartile in terms of % Black) and year. The dependent variable in each of these models is one of the eight crime rates and is explained using the lagged crime rate. Here we find some evidence that there may have been some changes in reporting that would be consistent with a decrease in the willingness to call the police (e.g., a significant structural break occurring with burglary and motor vehicle theft in 2015) but overall the changes are marginally significant or are likely reflective of sharp change in the trend occurring years before the death of Michael Brown. However, due to the limited number of observations and data quality, these results should be treated with skepticism.

[35] Available online at `https://www.bjs.gov/index.cfm?ty=nvat` (last accessed September 25, 2021).

[36] We thank Jacob Kaplan for making this suggestion.

[37] As expected, reported victimization is greater than the crime rates reported by the FBI - with the exception of larceny, which is due to the separation of theft and larceny in the NCVS.

Figure 11: Crime Trends by County Racial Demographics



Notes: Yearly crime rates (per 1,000 people) and gun dealers (per 1,000 miles) in counties with more than 11 % Black residents (top panel) and crime counts and gun dealers in counties with fewer than .9 % Black residents (bottom panel). Vertical line corresponds to 2014, the year of Michael Brown's death.

5 Discussion and Conclusion

We examine the effect of gun dealer density on county homicide rates. To our knowledge, we are the first to use a direct measure of gun prevalence at a county level on a national scale using plausibly causal panel data estimation techniques. We compare different measures of gun density and find that a halo measure that includes the county of interest as well as surrounding counties outperforms alternative measures. Our results indicate that homicide rates increase in the years following an increase in gun density. Additionally, gun density itself has no significant relationship with homicides not involving a gun. Furthermore, the estimated coefficients are consistent—in both magnitude and statistical significance—across three different estimation methods and two different data sources. Overall, the effect of gun density on homicides is small in magnitude.

We propose the small effect is due to gun dealer heterogeneity that is driven by multiple factors but among them differences in the types guns sold by gun dealers and the ebbs and flows of the market. To explore this possibility we interact gun dealer density with a number of county characteristics. Of the characteristics explored, we find the percentage of Black residents significantly increases the effect of gun dealer density on homicides while not having any effect on non-gun homicides. We show suggestive evidence that indicates that the composition of gun dealers in these counties shifts toward smaller gun dealers that

Figure 12: Crime Victimization Trends by Racial Demographics

Notes: Yearly crime victimization rates (per 1,000 people). Vertical line corresponds to 2014, the year of Michael Brown's death.

likely specialize in selling weapons designed for self-defense (i.e. handguns). In doing so we demonstrate the first evidence that the increase in violent crime in Black communities after 2014—known as the Ferguson Effect—was at least partially due to a sharp increase in gun density in those communities in the years just prior to and after Michael Brown's death. It is possible that the increase in gun availability plays a more important role in the increase in violent crime than previously explored causes, like changes in police behavior and decreased willingness of citizens to report crime. Future research could use our gun density measure to decompose the contributing factors of the Ferguson Effect in a more systematic fashion.

Considered more broadly, our results suggest that using county-level data allows for more control over unobserved heterogeneity between different areas, which can change how we assess the effects of policy changes. Moreover, using FFL data at the county level allows for a comprehensive measure of gun availability, which is important considering that the effectiveness of gun laws likely depends on the availability of guns. Future research could also use our gun density to explore the heterogeneity of the effect of gun law by gun density.

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A Appendix

A.1 FFL Details

Most of the FFL data was obtained from the ATF through a Freedom of Information Act request submitted in May of 2019. In the request, we asked for the number of FFLs issued by county, year, and type going back to 1987. The ATF filled our request by sending us a list of FFLs (usually from January and not including Type 3 FFLs) for each year from 2003 to 2013 along with the name, address, and (when applicable) business name of the FFL holder. Type 3 Licenses—issued to firearm collectors—were not included presumably because Type 3 firearms are not used like a typical firearm.[38] Regrettably, the ATF was unable to locate any FFL data older than 2001.[39] FFL data for the years 2014 - 2018 was found on the ATF's website.[40]

The ATF assigns a fifteen digit FFL numbers to each approved applicant. An example of a typical (but fictional) FFL is provided in Table A1. As can be seen in Table A1, each license can be broken into six sections and these sections identify the state and county of the license holder as well as the license type. State (technically Internal Revenue Service district number – which maps to a state) and county of the license holder are identified by the second and third section of the license number while the fourth section identifies the license type. The fifth and sixth section give the license expiration date and a unique identifier, respectively.[41] So in the example FFL provided in Table A1, one can infer the license holder is in Los Angeles County California and is an importer of Firearms/Ammunition. Last, the license expired in January of 2016.

Table A1: Example FFL

Division	IRS District	County	Type	Expiration Date	Unique
9	33	037	08	6A	75309

Notes: Fictional FFL number broken up by section.

[38] Specifically, Type 3 licenses are issued to individuals who are buying firearms that are considered to be "of special interest to collectors by reason of some quality other than is associated with firearms intended for sporting use or as offensive or defensive weapons." To qualify as a Curio or Relic (C&R) firearm, one of three qualifications must be met: i) the firearm must have been manufactured 50 years from the current date, ii) the firearm must have been certified as a C&R by the curator of museum which exhibits firearms, or iii) derive a substantial portion of its monetary value from its novelty, rarity, or relationship to some historical event.

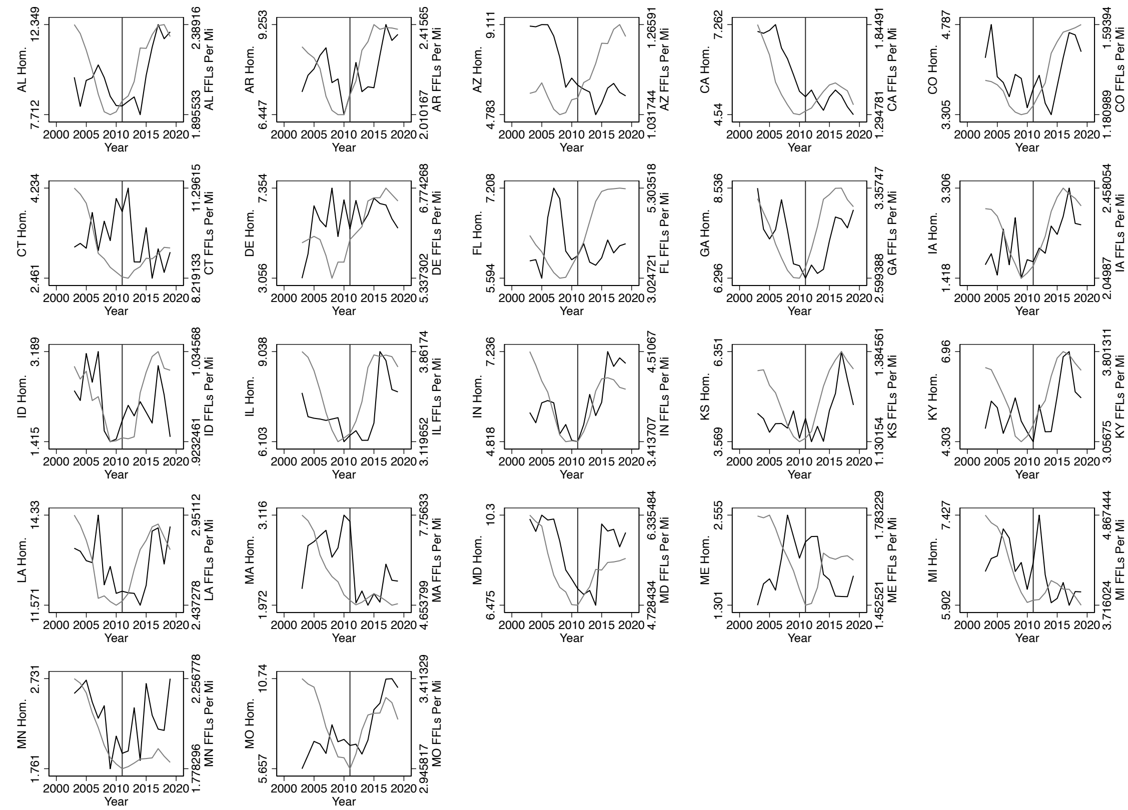
[39] The ATF did send data from 2001 but was unable to locate any data from 2002. We do not use the 2001 data because it was not as detailed as what was provided in the other years.

[40] The data provided online does not include any information relating to the Type 3 licensees.

[41] The numerical digit in the fifth section gives the expiration year while the letter corresponds to month. Because licenses are valid for 3 years, only a single digit is needed to determine if the FFL is expired.

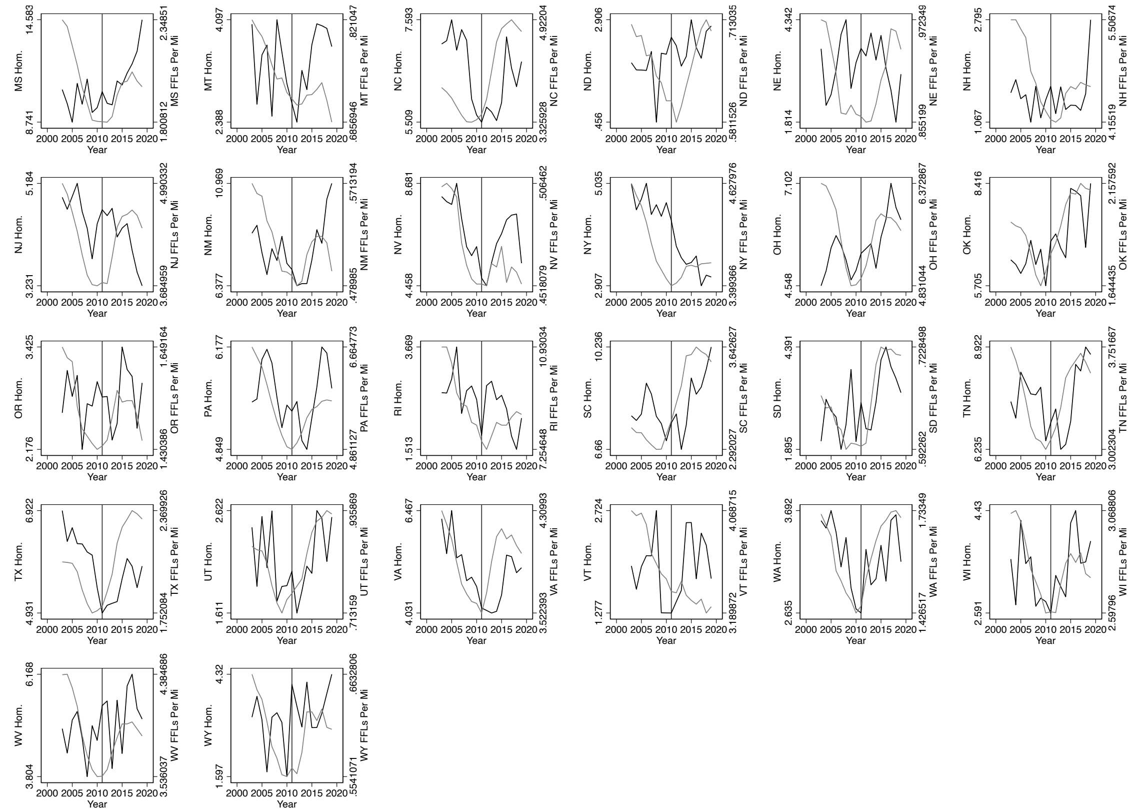
A.2 Gun Death Trends by US State

Figure A1: Homicide Rate and Gun Density by Year and State (AL - MO)



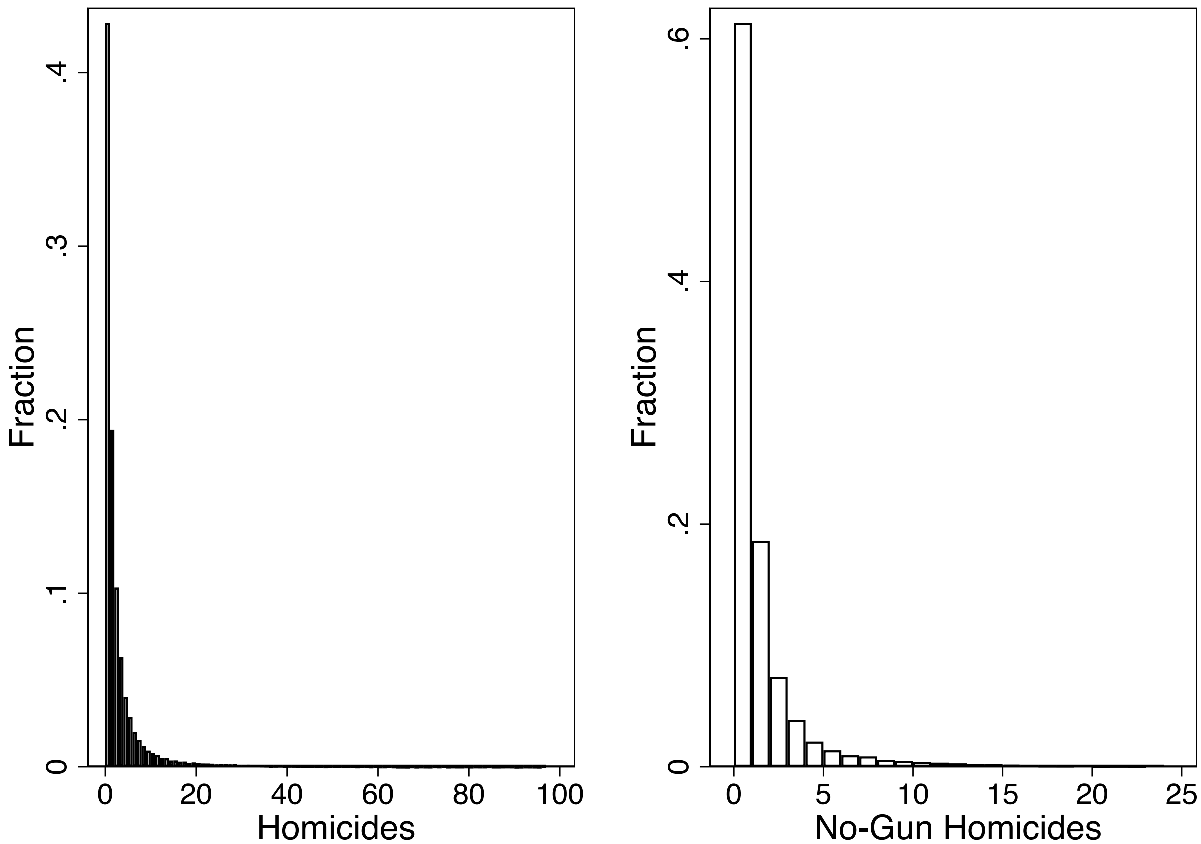
Notes: Homicide Rates (per 100 thousand people) and FFLs per 1,000 people by state and year. Solid line corresponds to a simple non-linear time trend. From top left to bottom right: Alabama, Arkansas, Arizona, California, Colorado, Connecticut, Delaware, Florida, Georgia, Iowa, Idaho, Illinois, Indiana, Kansas, Kentucky, Louisiana, Massachusetts, Maryland, Maine, Michigan, Minnesota, and Missouri.

Figure A2: Homicide Rate and Gun Density by Year and State (MS - WY)



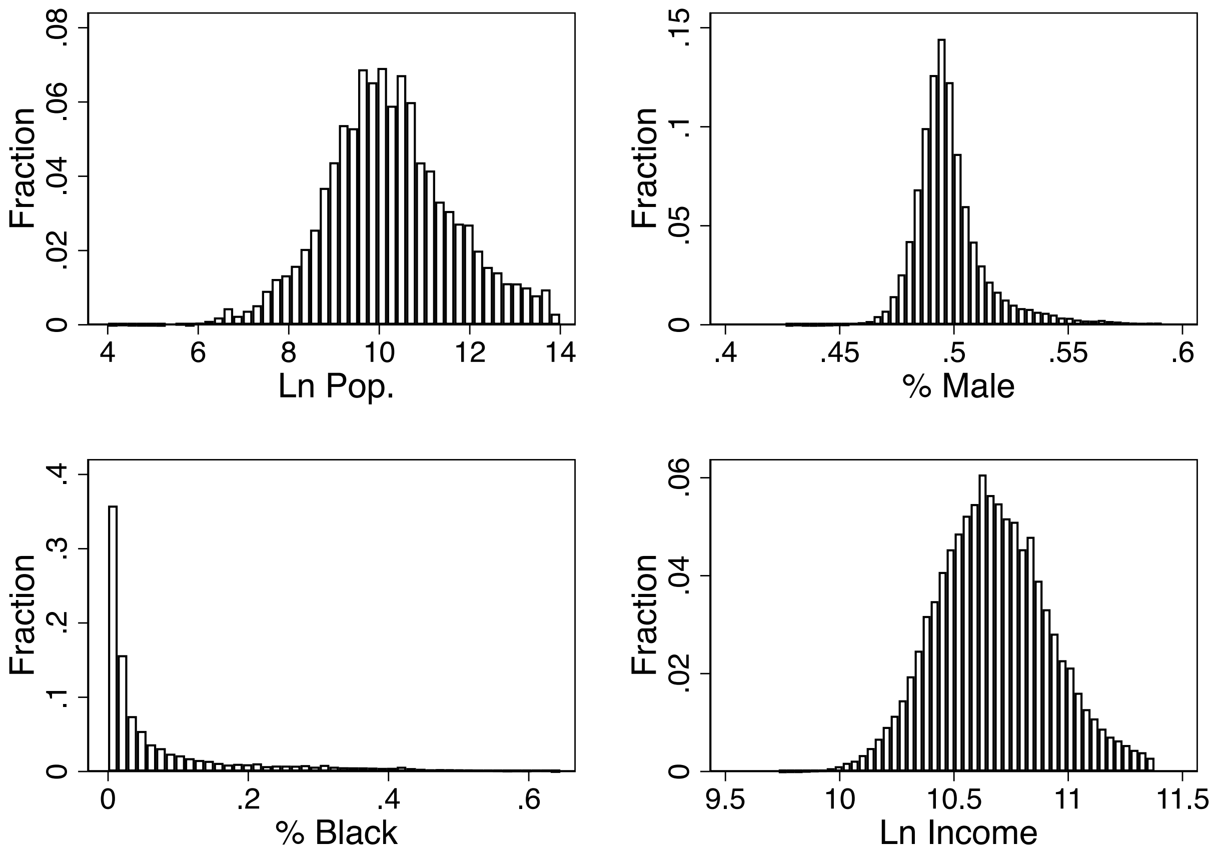
Notes: Homicide Rates (per 100 thousand people) and FFLs per 1,000 people people by state and year. Solid line corresponds to a simple non-linear time trend. From top left to bottom right: Mississippi, Montana, North Carolina, North Dakota, Nebraska, New Hampshire, New Jersey, New Mexico, Nevada, New York, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, Vermont, Washington, Wisconsin, West Virginia, and Wyoming.

Figure A3: Histograms of Deaths



Notes: Distribution of deaths per county per year. Left-hand panel: Homicides; Right-hand panel: homicides not involving a firearm. Both figures use data compiled by the CDC.

Figure A4: Histograms of Explanatory Variables



Notes: Distribution of the explanatory variables. From top left to bottom right: i) natural log of county population, ii) percentage of the population identifying as male, iii) percent of the county population identifying as Black, and iv) the natural log of median county income.

A.3 Results using Anderson-Hsaio Estimation

Table A2: The Effect of Guns Density on Total Homicides (CDC)

	Anderson and Hsiao					
	%GS	FFL PC	FFL PM	%GS(H)	FFL PC(H)	FFL PM(H)
Gun Dens.	-0.0030	0.0069	0.0096***	-0.011	0.043	0.023***
	(0.0085)	(0.016)	(0.0033)	(0.026)	(0.11)	(0.0075)
Ln Pop.	-0.33*	-0.33*	-0.34*	-0.34*	-0.33	-0.33*
	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)
% Male	0.96	0.96	0.98	0.99	0.96	0.97
	(1.07)	(1.07)	(1.07)	(1.09)	(1.07)	(1.07)
% Black	1.00	1.00	1.01	1.01	0.99	1.01
	(1.31)	(1.31)	(1.31)	(1.31)	(1.31)	(1.31)
Ln Income	0.061	0.061	0.060	0.063	0.061	0.058
	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)
LD.Hom.	-0.0056	-0.0054	-0.0054	-0.0052	-0.0054	-0.0054
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
R^2	0.0057	0.0056	0.0056	0.0053	0.0055	0.0056
LL	-32412.9	-32415.3	-32414.2	-32318.4	-32416.4	-32413.9
Counties	3071	3071	3071	3071	3071	3071
Observations	42994	42994	42994	42915	42994	42994

Notes: Each column corresponds to a different measure of gun density. From left to right: percent of gun suicides as a share of total suicides, FFLs per 1000 county residents, FFLs per 100 square miles, percent of gun suicides in the local area over the total suicides in the local area (halo), FFLs in the local area per 1,000 local area residents (halo), and FFLs in the local area per 1,00 square miles (halo). Dependent variable in each of the models is the inverse hyperbolic sine of the homicide rate. All models include county-specific linear time trends and county fixed effects and have standard errors clustered at the county level. Stars correspond to statistical significance: *** $p < 0.01$, ** $p < 0.05$, and *$p < 0.1$.

Table A3: Guns Density and Non-Gun-Related Homicides

	Anderson and Hsiao					
	%GS	FFL PC	FFL PM	%GS(H)	FFL PC(H)	FFL PM(H)
Gun Dens.	-0.0069	-0.0078	0.0056*	-0.010	0.0043	0.0067
	(0.0055)	(0.013)	(0.0030)	(0.018)	(0.071)	(0.0046)
Ln Pop.	-0.18	-0.18	-0.19	-0.19	-0.18	-0.18
	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)
% Male	0.38	0.38	0.39	0.41	0.38	0.38
	(0.77)	(0.77)	(0.77)	(0.78)	(0.77)	(0.77)
% Black	0.15	0.14	0.15	0.14	0.15	0.15
	(0.82)	(0.82)	(0.82)	(0.82)	(0.82)	(0.82)
Ln Income	0.052	0.051	0.051	0.053	0.051	0.051
	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)
LD.Hom. (NG)	-0.011	-0.011	-0.011	-0.011	-0.011	-0.011
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
R^2	0.011	0.011	0.011	0.011	0.011	0.011
LL	-15775.8	-15780.0	-15776.8	-15744.5	-15779.3	-15778.5
Counties	3071	3071	3071	3071	3071	3071
Observations	42994	42994	42994	42915	42994	42994

Notes: Each column corresponds to a different measure of gun density. From left to right: percent of gun suicides as a share of total suicides, FFLs per 1000 county residents, FFLs per 100 square miles, percent of gun suicides in the local area over the total suicides in the local area (halo), FFLs in the local area per 1,000 local area residents (halo), and FFLs in the local area per 1,00 square miles (halo). Dependent variable in each of the models is the inverse hyperbolic sine of the homicide rate. All models include county-specific linear time trends and county fixed effects and have standard errors clustered at the county level. Stars correspond to statistical significance: *** $p < 0.01$, ** $p < 0.05$, and *$p < 0.1$.

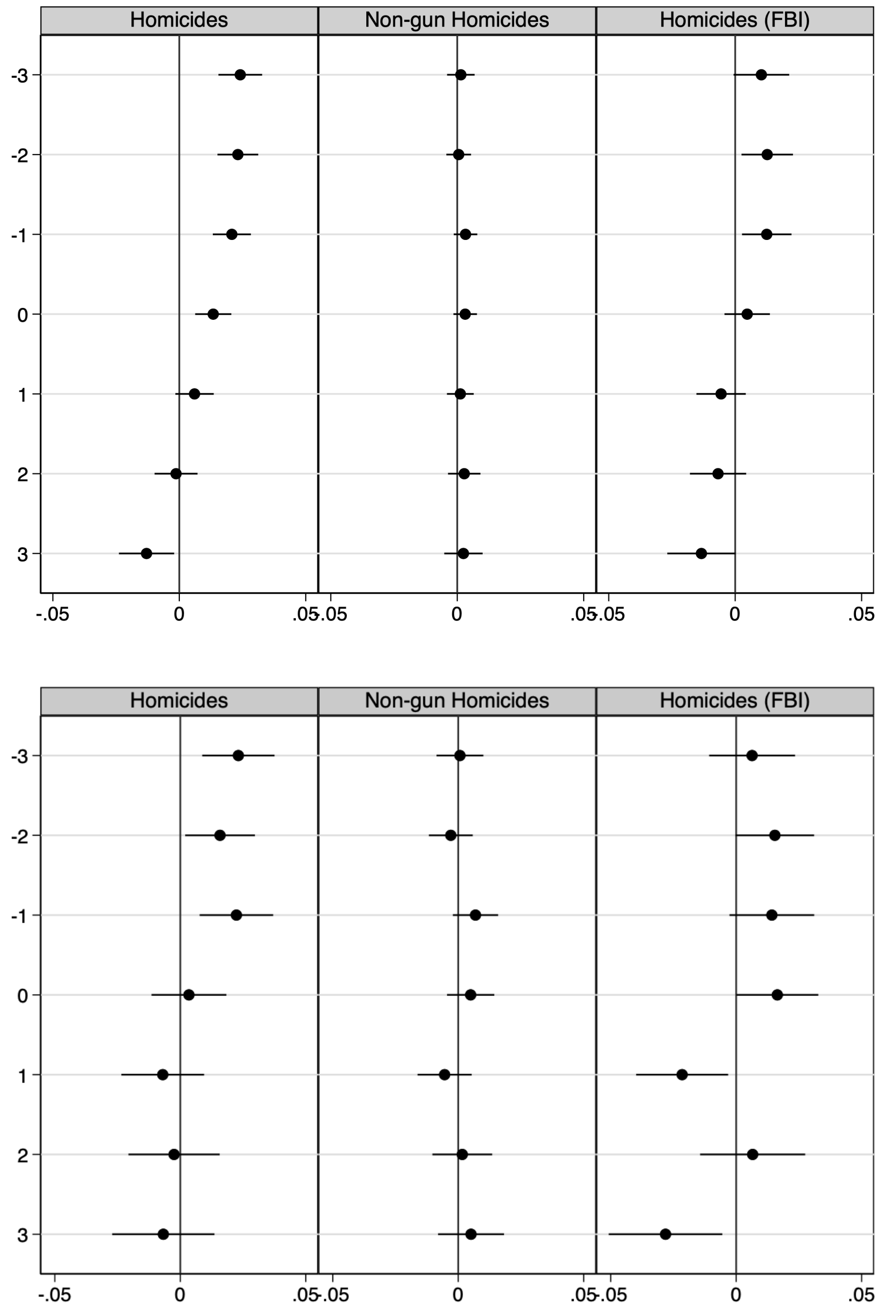
Table A4: Guns Density and FBI Measured Homicide Rates

	Anderson-Hsaio					
	%GS	FFL PC	FFL PM	%GS(H)	FFL PC(H)	FFL PM(H)
Gun Dens.	-0.016**	-0.028	0.0049**	-0.022	-0.040	0.016**
	(0.0080)	(0.023)	(0.0020)	(0.025)	(0.093)	(0.0068)
Ln Pop.	-0.087	-0.077	-0.087	-0.083	-0.088	-0.082
	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)
% Male	0.37	0.42	0.38	0.30	0.37	0.38
	(0.99)	(0.99)	(1.00)	(1.00)	(0.99)	(1.00)
% Black	2.03	1.99	2.01	2.16*	2.02	2.01
	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)	(1.24)
Ln Income	0.047	0.045	0.045	0.050	0.046	0.044
	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)
Hom. (FBI)	0.023	0.024	0.024	0.024	0.024	0.023
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Off. Per Cap.	5.84	5.95	5.94	5.94	5.94	5.98
	(8.59)	(8.59)	(8.59)	(8.59)	(8.59)	(8.59)
% Report	0.17	0.17	0.17	0.18	0.17	0.17
	(0.19)	(0.19)	(0.19)	(0.19)	(0.19)	(0.19)
% Rep. X Ln Pop	-0.0042	-0.0048	-0.0046	-0.0051	-0.0048	-0.0044
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
R^2	-0.021	-0.022	-0.022	-0.023	-0.022	-0.022
LL	-26197.8	-26223.1	-26221.0	-26147.4	-26222.0	-26217.3
Counties	3058	3058	3058	3057	3058	3058
Observations	40887	40887	40887	40849	40887	40887

Notes: Each column corresponds to a different measure of gun density. From left to right: percent of gun suicides as a share of total suicides, FFLs per 1000 county residents, FFLs per 100 square miles, percent of gun suicides in the local area over the total suicides in the local area (halo), FFLs in the local area per 1,000 local area residents (halo), and FFLs in the local area per 1,00 square miles (halo). Dependent variable in each of the models is the inverse hyperbolic sine of the homicide rate. All models include county-specific linear time trends and county fixed effects and have standard errors clustered at the county level. Stars correspond to statistical significance: *** $p < 0.01$, ** $p < 0.05$, and *$p < 0.1$.

A.4 Robustness Check: Different Leads and Lags of Gun Density

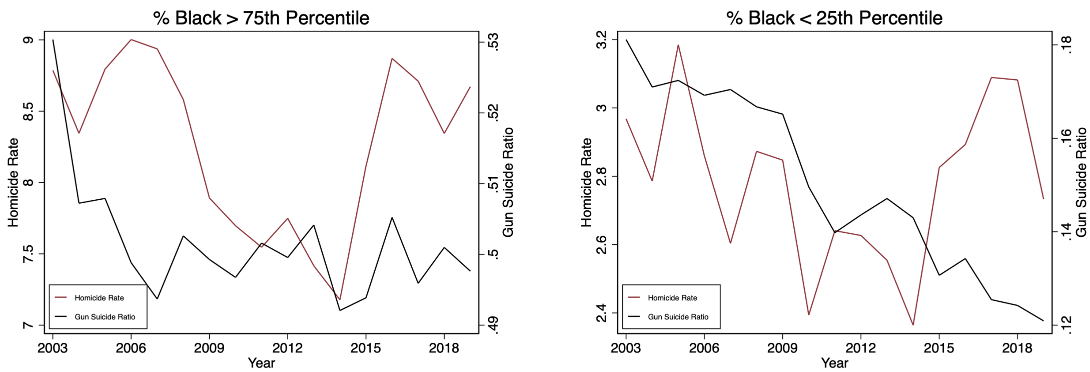
Figure A5: Different Lags and Leads of Gun Density



Notes: Estimates of Equation 3 using OLS (top) and Equation 4 using Anderson-Hsaio (bottom) using various lags and leads of our preferred measure of gun density FFLs PM(H). Other variables included in each of these models: the natural log of the county's population, the percent of the county identifying as male, the percent of the county identifying as Black, and the natural log of the county's median income.

A.5 Gun Prevalence as Measured by the Percent of Suicides Committed with a Gun

Figure A6: Effect of Guns on Homicide by Racial Composition using GS/TS



Notes: Total homicides and Gun Dealers in highly Black communities (left) and communities with percentage of Black residents below the median (right).

A.6 Robustness Check: Business Establishments per Mile

Table A5: Gun Dealer Density and County Characteristics

	Homicides			Non-Gun Homicides		
	Linear FE	A-H	Poisson FE	Linear FE	A-H	Poisson FE
Business Density	0.0000099	0.000029	-0.00014***	-0.000015	0.0000063	-0.000052*
	(0.30)	(0.80)	(-4.29)	(-0.88)	(0.32)	(-1.78)
% Male	0.27	0.97	-2.40	0.42	0.39	3.67
	(0.30)	(0.90)	(-0.91)	(0.72)	(0.50)	(1.16)
% Black	1.43	1.01	-0.12	0.76	0.16	1.54
	(1.37)	(0.77)	(-0.05)	(1.07)	(0.19)	(0.74)
Ln Income	0.22***	0.061	0.81***	0.083***	0.053	0.28***
	(5.50)	(1.13)	(9.09)	(3.06)	(1.47)	(3.31)
Ln Pop.	-0.48***	-0.33*		-0.12	-0.19	
	(-3.58)	(-1.68)		(-1.16)	(-1.51)	
Observations	46125	43050	43560	46125	43050	40800

Notes: Estimated relationship between business establishment density and Homicides (left three columns) and Non-Gun Homicides (right three columns). Columns correspond to the estimation method: linear fixed effects with IHS transformed dependent variables, Anderson-Hsaio dynamic estimator with IHS transformed dependent variables, and fixed effects poisson, respectively. Stars correspond to statistical significance: *** $p < 0.01$, ** $p < 0.05$, and *$p < 0.1$.

A.7 Robustness Check: Aggravated Assault/Homicides with a Gun

Table A6: Effect of Gun Density on Aggravated Assault/Homicides with a Gun

	Fixed Effects			Anderson-Hsaio		
	AA w/Gun	%AA w/Gun	%Hom w/Gun	AA w/Gun	%AA w/Gun	%Hom w/Gun
FFL PM (H)	0.031***	0.0035***	0.018***	0.028***	0.0028***	0.024***
	(0.0080)	(0.00043)	(0.0044)	(0.0100)	(0.00075)	(0.0085)
% Male	-1.30	-0.21	-0.14	-1.29	-0.086	0.38
	(1.37)	(0.14)	(0.52)	(1.72)	(0.20)	(0.60)
% Black	3.22**	0.16	0.39	2.01	0.096	0.85
	(1.49)	(0.11)	(0.68)	(1.83)	(0.13)	(0.93)
Ln. Pop.	0.25***	0.020***	0.075**	0.066	0.0048	0.016
	(0.067)	(0.0048)	(0.034)	(0.083)	(0.0058)	(0.047)
Ln Income	-0.12	-0.040**	-0.12	0.0096	-0.019	0.060
	(0.22)	(0.017)	(0.094)	(0.28)	(0.020)	(0.082)
LD.AA w/Gun				0.0094		
				(0.018)		
LD.%AA w/Gun					0.017	
					(0.034)	
LD.%Hom w/Gun						0.00017
						(0.014)
R^2	0.77	0.42	0.40	-0.0083	-0.016	-0.000034
LL	-38554.8	88117.2	-13399.9	-49089.4	63411.6	-29529.3
Counties	3071	3053	3071	3071	3010	3071
Observations	49136	46937	49136	42994	39743	42994

Notes: Estimated relationship between gun dealer density and Aggravated Assault and Homicides with a gun. Columns correspond to the dependent variable: IHS of the aggravated assaults committed with a gun, percent of aggravated assaults that used a gun, and percent of homicides that involved a gun. Main headings indicate estimator (Linear Fixed Effect and Anderson-Hsaio. Stars correspond to statistical significance: *** $p < 0.01$, ** $p < 0.05$, and *$p < 0.1$.

Table A7: Effect of Gun Density on Aggravated Assault with a Gun (LEAs that Fully Report)

	Fixed Effects		Anderson-Hsaio	
	AA w/Gun	%AA w/Gun	AA w/Gun	%AA w/Gun
FFL PM (H)	0.048***	0.0039***	0.051***	0.0033***
	(0.0076)	(0.00049)	(0.0098)	(0.00076)
% Male	-1.98	-0.33**	-1.06	-0.20
	(1.58)	(0.15)	(2.09)	(0.19)
% Black	2.81*	0.077	1.42	0.023
	(1.54)	(0.12)	(1.94)	(0.13)
Ln. Pop.	0.23***	0.014***	0.054	0.0030
	(0.070)	(0.0050)	(0.088)	(0.0060)
Ln Income	-0.47*	-0.017	-0.21	-0.0084
	(0.27)	(0.018)	(0.23)	(0.018)
LD.AA w/Gun			0.0043	
			(0.019)	
LD.%AA w/Gun				0.032
				(0.030)
R^2	0.78	0.43	-0.0037	-0.029
LL	-28606.7	75574.3	-37749.0	54622.0
Counties	2467	2463	2467	2460
Observations	39472	39108	34538	33854

Notes: Estimated relationship between gun dealer density and Aggravated Assault with a gun. Columns correspond to the dependent variable: IHS of the aggravated assaults committed with a gun and percent of aggravated assaults that used a gun. In all models here we use only data from law enforcement agencies that reported data to the FBI for more than 7 or more months of a given year. We also drop LEAs that did not submit crime data for one or more years of the panel. Main headings indicate estimator (Linear Fixed Effect and Anderson-Hsaio. Stars correspond to statistical significance: *** $p < 0.01$, ** $p < 0.05$, and *$p < 0.1$.

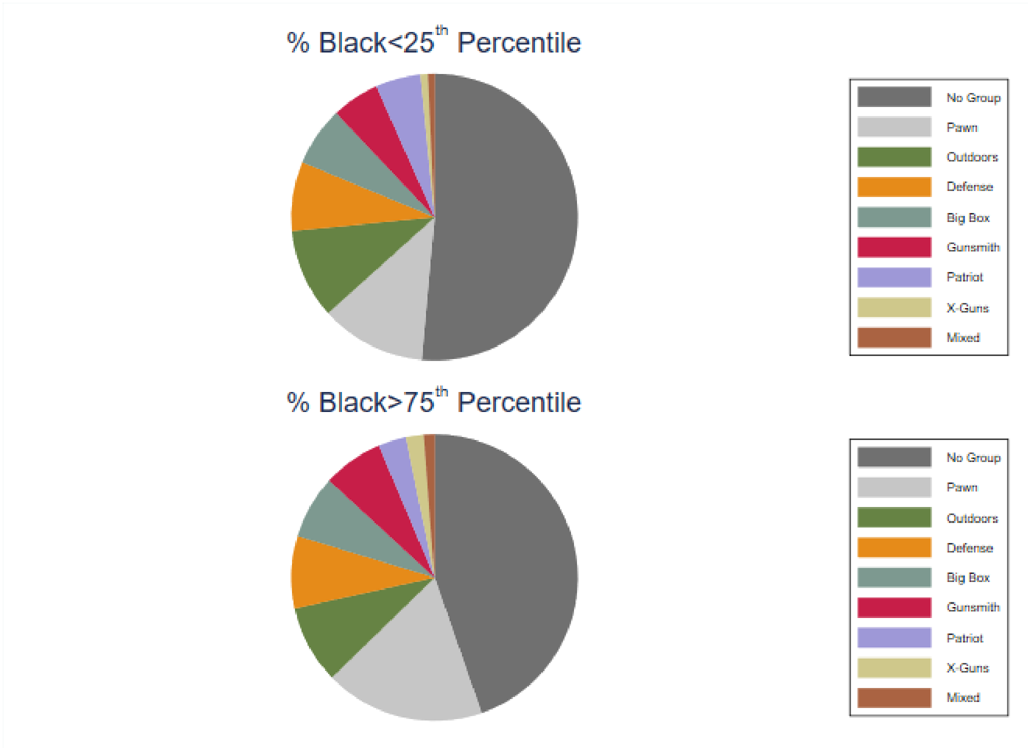
A.8 Classifying FFLs by Name

Below are the classification key words. To create the classifications, we first dropped all non-alpha numeric characters and spaces in the business name and capitalized each letter (e.g., Dick's was changed to DICKS). We then searched for the following strings. The strings we searched for were selected based on popularity.

- **Outdoors**: CAMP, HUNT, OUTFIT, GAME, FISH, SUPPLY, OUTDOOR, SPORT.
- **Defense**: TACTICAL, DEFENSE, DOUBLETAP, LAWENFOR, GUARDIAN.
- **Big-box**: WALMART, BASS, SPORTSAU, CABELAS, DICKS, DUNHAMS, BI-MART, BIG5, GANDER, ACEHARD, RURALKI, ATWOODS, KMART.
- **Gunsmith**: GUNSMITH, REPAIR.
- **Patriot**: 2A, SECONDA, AMERICAN, PATRIOT, 2ND, LIBERTY, HERITAGE, FREEDOM, EAGLE.
- **Name**: DAVE, BILL, BOB, RAY, JIM, JOHN, MIKE, STEVE, GARY, FRED, WILL, TOM, RICK, LARRY, JERRY, DON, RON, GREG, JOE, PAUL, TIM, FRANK, DAN, WAYNE, TERRY, PETE, RICHARD, MARKSG, LEES, KEN, JEFF, JACK, MITCHEL, MICHAEL, ROGER, SCOTT, THOMPSON, MARSHAL, GENE, GEORGE, EDSGUN, DOCS, DOUG, CHUCK, CHARLIE, ROBERT, ROBINSON, STEWART, RUSSELLS, RANDY.

A.9 Gun Dealer Composition

Figure A7: Gun Dealer Composition (2016)



Notes: Share of FFLs by classification in counties in the upper and bottom quartile of percent of Black residents. Year is 2016.

A.10 Structural Break Tests

Table A8: Known Structural Break Test Results

	% Black $< 25^{th}$ Percentile							
	A. Assualt	Arson	Burglary	Larcney	MVT	Robbery	Homic (FBI)	Homic (CDC)
2011	.175	.133	.056	.648	0	0	.366	.715
2012	.152	.269	.05	.156	.001	0	.33	.669
2013	.157	.001	0	0	.08	.002	.431	.669
2014	.069	.039	.047	.412	.157	.103	.536	.49
2015	0	.002	.608	.868	.127	.132	.735	.034
	% Black $> 75^{th}$ Percentile							
	A. Assualt	Arson	Burglary	Larcney	MVT	Robbery	Homic (FBI)	Homic (CDC)
2011	0	.665	.012	.389	.14	.723	.583	.89
2012	0	.973	0	.424	.187	.669	.39	.476
2013	.083	.515	0	.185	.033	.67	.601	.759
2014	.079	.85	.001	.416	.077	.602	.336	.394
2015	.078	.963	.001	.613	.07	.652	0	0

Notes: Structural Break tests results (p-values). Null hypothesis is that there is no structural break in year 2011, 2012,..., 2015. All models use county collapsed crime data that is further collapsed to by year and county "type". Counties with incomplete observations are dropped. Type depends on the percent of the county that identifies as Black (top and bottom quartile). Estimates all use the same specification ($E[y_t] = \beta_0 + \beta_1 y_{t-1}$) where y is one of the eight crime rates ($N = 17$).