Where are the Guns?

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Abstract

We test the effectiveness of several common gun prevalence proxy variables against what are arguably the best measures of gun prevalence: firearm sales and concealed carry permits. With a comprehensive count of gun sales and concealed carry permits (by county and year) in the states of Pennsylvania and Massachusetts, we make two main observations: First, gun sales/concealed carry permits are positively correlated with federal firearm licenses (gun dealers) per mile. Second gun sales/concealed carry permits are not significantly positively correlated with federal firearm licenses per capita or the proportion of gun suicides to total suicides. We then discuss why this occurs and the limitations of using legal gun sales as a gun prevalence measure. Last, we show how the competing measures differ in terms of their associations with gun homicide. We find our preferred measure to have a strong positive association with gun homicides while many others do not. Consequently, we advise researchers to use gun dealers as a measure of gun prevalence and specifically in a way that considers markets bleeding over arbitrary lines (e.g., county, city, or neighborhood). This will especially be the case if one is interested in small geographic areas.

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1 Introduction

From 1999 to 2019, there were nearly 700,000 firearm-related deaths in the United States. From a societal and policy perspective, determining the effect of gun prevalence on violent crime and gun death rates (homicides, suicides, and accidents) is important for informed policy.[1] Researching this question is complicated by The Firearm Owners Protection Act of 1986, which limits gun transaction data.[2] Nevertheless, estimates of gun prevalence exist in the form of various proxy measures. To date, which proxy (or combination of proxies) best represents firearm availability remains an open question.

In this study, we use a novel dataset on reported legal gun sales and concealed carry permits in the states of Pennsylvania and Massachusetts to assess the ability of popular indirect gun prevalence measures to capture the variation in these two direct gun prevalence measures.[3] We show reported legal gun sales are *inversely* correlated with the percentage of suicides committed with a firearm and Federal Firearm Licenses (FFLs) per capita. In contrast, other FFL-based measures are positively correlated with gun sales—particularly handguns—and concealed carry permits (which are also negatively correlated with the percentage of suicides committed with a firearm). This changes some when including county and year fixed effects, though two main results remain: i) handgun sales are positively and significantly correlated with FFL dealers and FFL dealers per mile, and ii) concealed carry permits are significantly positively correlated with gun sales and FFL-based measures that are not population-based.

Additionally, we also show that even when using seemingly ideal measures of gun prevalence (gun sales and concealed carry permits) researchers must pay attention to the spatial nature of gun sales. Using a database of traced crime guns from the Pennsylvania Attorney General's office from 2003 to 2020, we find that only around half of the guns successfully traced to an FFL in Pennsylvania were traced to a dealer in the same county where they were recovered. Further, and consistent with **?** and **?**, guns that were recovered in a different county were often traced to an adjacent county (i.e., the two counties share a border). Lastly, we show how the relationship between gun prevalence and gun homicide depends on the measure of gun prevalence being used. We show that our preferred measures (concealed carry permits and area-based FFL measures) are both significantly and positively correlated with gun homicides which is consistent with the weakness of the other possible proxy measures. Given this, the limited availability of gun sales/concealed carry data, and the strong correlation between gun sales/concealed carry permits and land-based FFL density, we advise researchers to use FFL density as a measure of gun prevalence. This measure is available at all geographic levels (state, county, zip code, street address) for many years and can be used to create measures that account for markets crossing spatial boundaries.

The rest of the article proceeds as follows: Section 2 provides some background information, Section 3 introduces the main data, Section 4 discusses the results, and Section

[1] Because of the multiple data sets used (some using "gun" and some using "firearm") in the analysis, we use "gun" and "firearm" interchangeably. However, we note that "gun" is technically an umbrella term.

[2] Specifically, it prevents the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) from centralizing purchase records. This was later expanded in 1993 under the Brady Handgun Prevention Act of 1993 which required any record of a background check that led to a firearm transfer be destroyed.

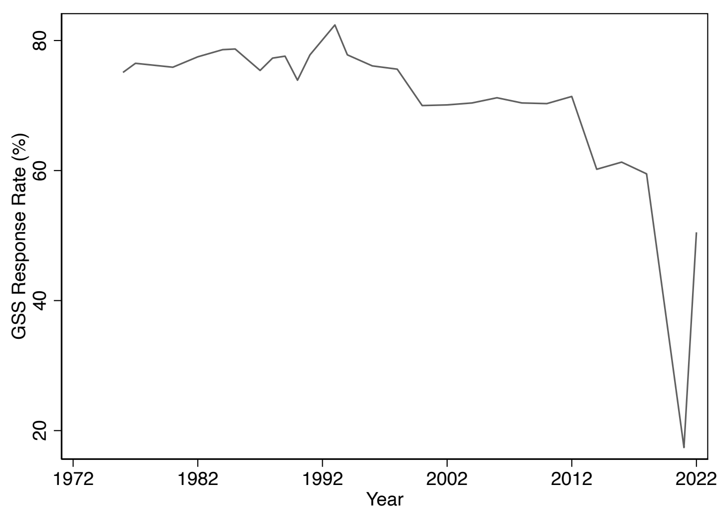
[3] We are not the first to investigate concealed carry permits (e.g., **???**) but note that these types of studies focus on law changes rather than the actual number of permits issued at the county level.

4.2 gives a practical example of how differences in measures of gun prevalence can lead to different relationships with gun homicide. Section 5 concludes.

2 Background

Due to the importance of understanding the relationship between gun prevalence and gun violence, there have been many attempts to capture the variation in gun prevalence indirectly through proxy measures. Some gun prevalence estimates are based on survey data. National surveys that ask gun-related questions include the Behavioral Risk Factor Surveillance System (BRFSS), the Gallup Poll, and the General Social Survey (GSS). All of these surveys, except for the BRFSS, are only representative at the national level, which make them inappropriate for use in examining finer geographies and, therefore, most firearms research. The BRFSS included core survey questions about gun ownership in only three waves (2001, 2002, and 2004), but several individual states continued to ask gun questions in the following years. Despite only being representative at the national level, the GSS, which has been conducted at least every two years since 1972, is still often used in gun-related research due to being the longest-running American survey that asks about gun ownership. Articles using survey data include **?**, **?** and **?** among others.

Figure 1: GSS Response Rate

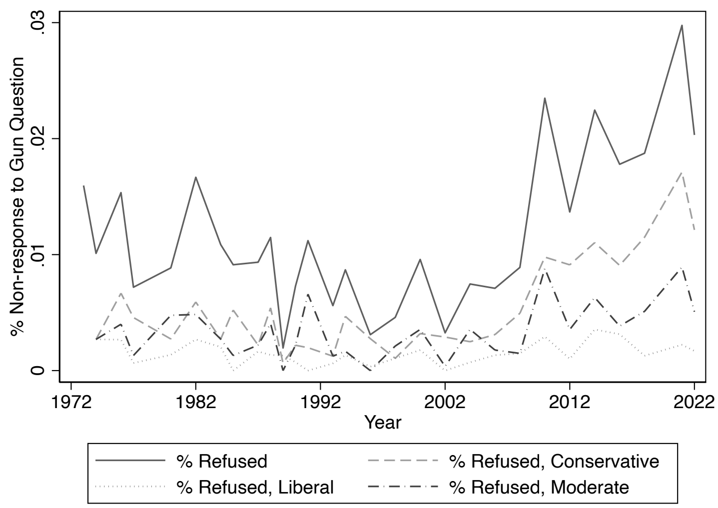


However, the accuracy of these surveys is an open debate. Response rates for national polls have dropped sharply over time. Response rates to Pew Research's telephone survey dropped from 36 percent in 1997 to only 6 percent in 2018, for example.[4] Similarly, even the GSS—which historically has very high response rates—has seen response rates plummet, as seen in Figure 1.

[4] https://www.pewresearch.org/short-reads/2019/02/27/response-rates-in-telephone-surveys-have-resumed-their-decline/

? argues some individuals may not answer survey questions truthfully, thus underestimating the percentage of gun-owning households. **?** shows evidence for this in the GSS, particularly amongst conservative respondents. More recently, **?** show that more than a third of survey respondents may be underreporting firearm ownership.[5] This can be seen in the GSS data in Figure 2.

Figure 2: Non-responses to Gun Question



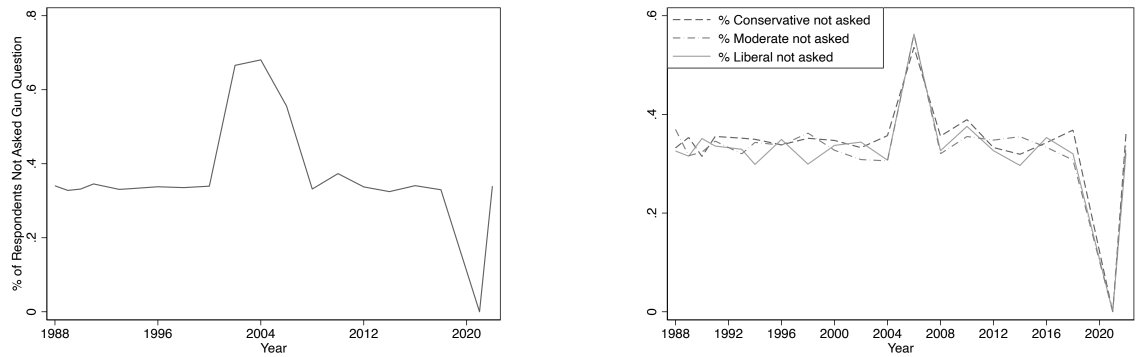
The percentage of individuals who refused to answer the gun ownership question increased sharply after the 2008 election, particularly among conservative and moderate respondents. It is also worth noting that the GSS regularly fails to ask large percentages of respondents a question about gun ownership due to its split-ballot design. As seen in Figure 3, more than a third of respondents are regularly not asked, and the percentage nearly doubled in the 2000s, with conservative and moderate respondents proportionally less likely to be asked the question in most years.

Due to the quality issues inherent in survey data, researchers frequently use other constructed proxies for gun ownership. The most popular in recent years is the percentage of suicides committed with a firearm (henceforth %GS) (e.g. **?????**).[6] **?** and **?** report high correlations between %GS and gun ownership rates reported in GSS and BRFSS surveys. However, **?** notes that it is likely not a valid proxy in a panel data or time series analysis. Monthly and yearly state-level firearm background checks, which the FBI has reported since 1999, are another indirect measure used in recent studies (**??**). Other proxy measures include hunting licenses per capita (**?**), combining hunting licenses per capita with %GS (**?**), Google searches for gun-related terms (**?**), and magazine subscriptions to a gun interest magazine (**?**). **?** and **?** provide summaries and critiques of gun prevalence proxies. **?** test several proxy measures available at the county level and conclude that federal firearm

[5]It is important to note that their methodology does not allow them to confirm whether the respondents actually own a firearm, however.

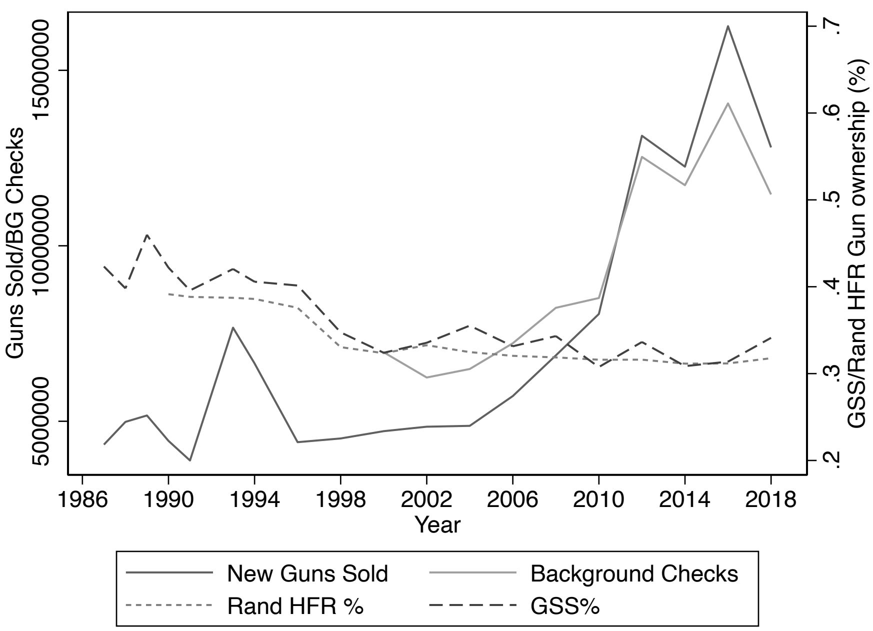
[6]We note that %GS is often reported as FS/S (for firearm suicides divided by total suicides). We use %GS rather than FS/S because of the latter's similarity with other abbreviations we will be using.

Figure 3: Proportion Not Asked Gun Question



licenses per capita have the highest correlation with national survey data but also make it clear that this measure could be improved.

Figure 4: HFR vs Gun Proxies



?? attempted to construct a measure of the state-level household firearm ownership rate (HFR) by combining all of the available surveys with several of the above proxy measures of gun prevalence. They prioritize the survey data in their latent variable construction and argue that surveys are better than proxy variables because the nature of the proxy and gun ownership may vary over time or be noisy for certain groups (**?**). However, as we show above, the quality of survey data is definitely changing over time, and the lack of survey data for smaller geographies likely results in overfitting. For example, you can clearly see there is very little discernible difference between the HFR and GSS household gun ownership percentage in Figure 4. Even if we assume the HFR is calculated correctly, however, the reality is that it is likely not an informative measure about gun prevalence—that is, how many guns are in circulation and how easy it is for an individual to acquire a gun. Figure 4 shows that while the HFR has been on a downward trend for the past 3 decades, the net yearly increase of manufactured firearms in the US approximately tripled over the same period, with background checks for firearm purchases showing a similar trend.[7] Furthermore, given the large amount of within-state variation in gun prevalence and gun violence (e.g. between urban and rural areas), state-level estimates likely do not provide enough information to help researchers understand how gun prevalence affects gun-violence (**?**).

Recently, **?** (J&R hereafter) attempt to more accurately capture the variation in gun prevalence by introducing a new proxy, gun dealer density (calculated as Federal Firearm Licenses per mile or FFLs PM).[8] There are a number reasons why changes in the number of FFLs in an area is a good indication of changes in gun prevalence. First, nearly every gun in circulation is initially transferred into public hands through a FFL. Additionally, the only legal way to ship guns (new or used) across state lines is through a FFL, so an additional FFL in an area is a good indication that more guns are being transferred to and/or sold in that area. Finally, the increase in retail gun stores will impact the availability and prices of guns in both legal and illegal non-retail markets and increase the opportunities for guns to stollen. Thus, a change in the number of gun dealers is likely indicative of broad changes in gun prevalence and trade, not just retail trade. For these reason, FFL-based gun prevalence measures are arguably better at capturing the variation in gun prevalence that is associated with gun-related crime.

Moreover, our gun prevalence measure differs from conventional population-based measures. Namely, instead of the denominator being some proportion of the population, it is the land area. This more accurately captures the cost of acquiring a firearm, since an individual's geographic proximity to a gun store is more important than the number of people a particular gun store may service. In practical terms, the gun density measure moves from rural areas (that have a high number of gun dealers per person) to more urbanized areas (that have more gun dealers per mile). The assumption here is that gun dealers in urban areas sell more guns than their rural counterparts—which, using gun sales data, we show is largely true. Additionally, this measure can be calculated at any geographic level (the ATF records include dealers' physical addresses), unlike most proxy measures that are only available at the state or national level.[9]

Arguably, the best measure of changes in gun prevalence is either actual gun sales or concealed carry permits. Unlike the other measures previously discussed, we consider both variables to be *direct* measures of the change in the number (flow) of guns into a community. It is impossible to know the existing number (stock) of firearms in an area at any given time. However, in econometric models that use area-level fixed effects, the

[7] Net number of manufactured firearms is calculated from domestic production plus imports minus exports as reported in the *Report on Firearms Commerce* produced annually by the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF).

[8] While slightly different, other researchers introduce related measures (e.g., **???**).

[9] We are not the first to note this benefit of FFLs. **?** uses this feature to demonstrate that FFLs in disadvantaged neighborhoods are associated with more shootings whereas the opposite is the case in advantaged neighborhoods.

stock of firearms is absorbed by the fixed effect, which means both gun sales and new concealed carry permits measure the rate at which guns enter the community (i.e. the *flow* of guns). These two measures have complementary weaknesses and strengths relative to an ideal measure that would link guns to individuals (i.e., a gun registry). For instance, while concealed carry permits link an individual with a gun to a specific county, it does not give any information about the number of guns owned by the individual. Gun sales might seem like an improvement, but the buyer of a gun often does not live in the county where they bought it. However, collectively, these two measure likely capture new gun prevalence quite well. We will use these two measures as a benchmark to assess which gun proxy variables best capture the variation in gun prevalence at the local level.

3 Data

Mortality data used to determine the %GS (and firearm homicide counts used in Section 4.2) are from the Centers for Disease Control and Prevention (CDC) Wonder Database. Population, race, and income data are from the US Census Bureau.[10] Business counts are from the County Business Patterns Survey. Federal Firearm License (FFL) data is from the ATF. Gun dealers are defined as individuals or businesses holding a Type 1 (gun dealer) or Type 2 FFL (pawn).

There are multiple sources of gun data. First, gun sales data for Pennsylvania is from the Pennsylvania State Police—specifically the Firearms Annual Reports (2003 - 2020).[11] These reports also contain FFL counts, the number of license-to-carry permits (concealed carry permits), and Sportsman's firearm permits, issued for each county.[12]

Gun sales data for Massachusetts originally came from a Freedom of Information Act request. This dataset is richer and, before being collapsed to the county-year, is the list of every firearm sale from 2006 - 2021 that took place at a licensed dealer. There are about 1.4 million transactions in this dataset. The original variables in these data include the following: the date of the sale, the address of the dealer/seller's city, the make and model of the firearm, and the firearm type (i.e., pistol, rifle, shotgun, and machine gun). We supplement this dataset with a list of private transactions reported to the state of Massachusetts over the same period. This leads to about 184 thousand more sales.[13] To make the Massachusetts data compatible with the Pennsylvania data, we rename the "pistol" type "handgun" and lump rifles and shotguns into a single "long-gun" category.[14] Permit data comes from the

[10]Population and race were accessed through the CDC Wonder database and income data come from the Small Area Income and Population Estimates Program.

[11]The firearm database and Annual Reports can be found here [public dropbox to be released].

[12]Readers who carefully examine both databases might note differences in the Pennsylvania FFL counts and the counts in the J&R database. The former bases the counts on January of a given year. The counts in the Pennsylvania Firearms Annual Reports are based on end-of-year counts. Further, there are some errors in the Pennsylvania Firearms Annual Report. For example, Philadelphia County generally has fewer than 15 FFLs but in 2015 this spiked to 63. This was not a spike in the number of FFLs in Philadelphia County but FFLs from neighboring counties (e.g., Montgomery) being wrongly put in Philadelphia County. The error was corrected the following year.

[13]The data fields in the two datasets are similar.

[14]We drop fully automatic gun sales as these types of guns make up only a tiny portion of transactions (i.e., less than 400 were sold from 2006-2021 in Massachusetts).

Massachusetts Firearms Records Bureau.[15] Massachusetts issues several types of permits but we are interested in only one: the Resident Class A Large Capacity License to Carry Firearms. We consider an individual who has a Resident Class A Large Capacity License to Carry Firearms to have a concealed carry permit.

In the Appendix, we also perform analysis using data from California. We keep this analysis separate from the rest of the paper for two reasons. First, this data is much newer than the Massachusetts and Pennsylvania data. The Freedom of Information Act (FOIA) data request was responded to on November 7, 2023. Second, the California data only has handgun sales data from 2000 to 2022. Long-gun data was not collected until 2014 and, according to the FOIA response letter, concealed carry permit records are only maintained for 2021 and 2022.[16] When applicable, we will note where the analysis using California data can be found. This information will always be found in the note of the relevant figure or table.[17]

Summary statistics for the variables of interest are found in Table 1. To create a balanced panel and to avoid COVID-related complications/breaks we only use data from 2006-2019. Variable descriptions are as follows: "Handguns (1,000s)" (i.e., revolvers and semiautomatic pistols) is the reported number of handguns sold in thousands, "Long-guns (1,000s)" is the reported number of long-guns sold (i.e., shotguns and rifles) in thousands, "CC Permits" is the number of license to carry permits issued by the state of Pennsylvania and the total number of Class A permits issued by the state of Massachusetts (thousands),"% GS" is the percentage of suicides that involve a firearm, "FFLs PM (H)" is the number of FFLs in a county plus the number of FFLs in the "halo" of counties surrounding the county divided by the land area of the counties (100 miles), "FFLs (Count)" is the number of gun dealers in the county, "FFLs (H)" is the number of FFLs in a county plus the number of FFLs in the "halo" of counties surrounding the county, "FFLs PM" is the number of FFLs in a county divided by the county's land area (100 miles), "FFLs PC" is the number of FFLs divided by the county population (10,000 people). "% Black" is the percent of the county population that identifies as Black, "U. Rate" is the unemployment rate, % Male is the percentage of the county population that identifies as male, Population is the county population,"Pop Density" is the number of people per mile, "Bus. PM (H)" are the number of establishments (businesses) per mile in county i and counties adjacent to i divided by the total land area in the county group, "Bus. (H)" is similar but only considers the count.

The "halo" measure (Equation 1) is constructed as follows:

$$FFLsPM(H)_{i,t} = \frac{\left(D_{i,t} + PW_{i,t} + \sum_{j=1}^{m}(D_{j,t} + PW_{j,t})\right)}{A_i + \sum_{j=1}^{m}(A_j)} \tag{1}$$

where $D_{i,t}$ and $PW_{i,t}$ are the number of Dealer and Pawnbroker licenses held in county i in year t, $\sum_{j=1}^{m}(D_{j,t} + PW_{j,t})$ is the total number of Dealer and Pawnbroker license in the

[15] This data can be found at https://www.mass.gov/info-details/data-about-firearms-licensing-and-transactions#license-applications-&-active-licenses. The sales data can now be found here as well.

[16] Historical concealed carry permit data is available but there is a notable gap. This data was collected by Trent "Tate" Steidley but seems to be no longer available publically. Author 1 can provide the data so long as the original author is properly cited.

[17] California handgun sales data can be found in author 1's publicly available dropbox file.

Table 1: Summary Statistics

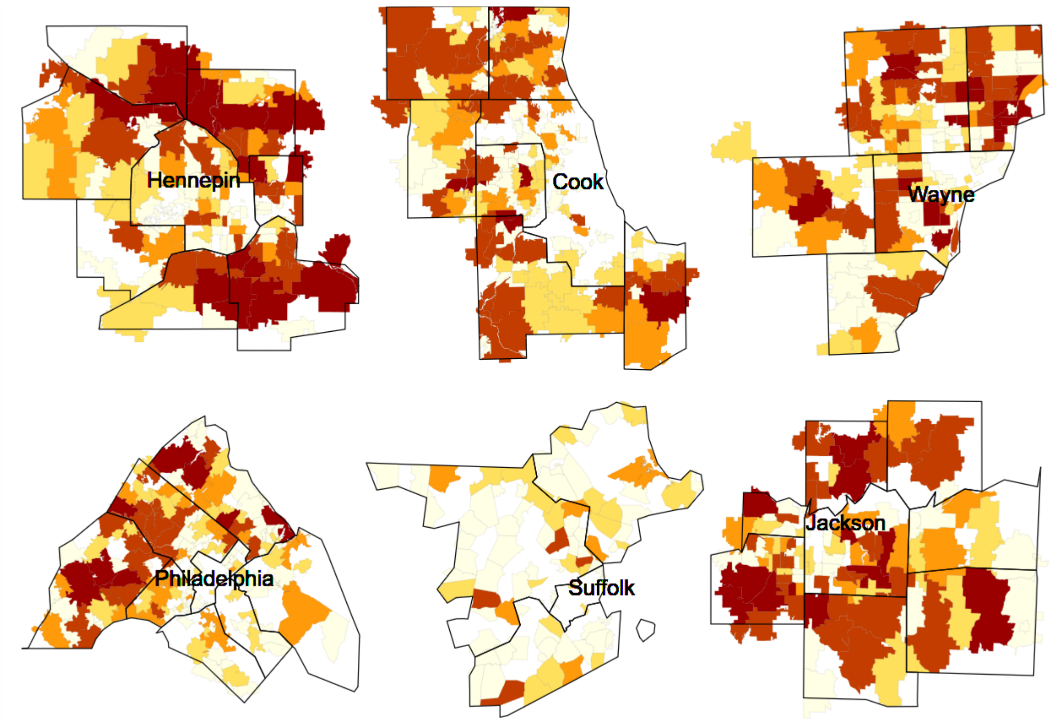
	Pennsylvania			
	Mean	Std. Dev.	Min	Max
Handguns (1,000s)	5.00	5.53	0.0070	35.2
Long-guns (1,000s)	4.71	4.55	0.0050	51.3
CC Permits (1,000s)	3.20	3.12	0.13	23.8
% GS	0.57	0.21	0	1
FFLs (H)	252.7	93.8	79	484
FFLs PM (H)	5.71	2.31	1.49	10.2
FFLs (Count)	36.2	24.4	3	152
FFLs PM (100s)	5.97	4.14	0.68	25.6
FFLs PC (10,000s)	3.79	2.39	0.072	14.8
Pop. (10,000s)	19.0	26.9	0.44	158.4
Pop. Density	469.6	1440.1	11.2	11813.1
U. Rate	6.35	1.89	3.13	17.1
% Male	49.9	2.52	46.9	68.9
% Black	5.20	6.74	0.39	46.6
Bus. PM (H)	825.8	710.6	94.0	3291.2
Bus. (H)	34304.5	26642.8	4996	119670
Year	2012.5	4.03	2006	2019
Observations	938			

	Massachusetts			
	Mean	Std. Dev.	Min	Max
Handguns (1,000s)	3.98	5.02	0	25.0
Long-guns (1,000s)	2.47	2.67	0	11.8
CC Permits (1,000s)	4.45	3.92	0.087	18.9
% GS	0.24	0.16	0	1
FFLs (H)	219.9	115.2	47	504
FFLs PM (H)	6.66	1.81	4.26	10.5
FFLs (Count)	28.6	21.3	0	83
FFLs PM (100s)	4.92	2.82	0	15.5
FFLs PC (10,000s)	0.84	0.67	0	2.93
Pop. (10,000s)	47.6	40.9	0.98	161.5
Pop. Density	1612.6	3192.6	100.4	13882.2
U. Rate	5.69	1.97	2.31	10.7
% Male	48.5	0.98	46.6	51.8
% Black	7.43	5.84	1.55	26.4
Bus. PM (H)	2110.7	921.4	571.4	3646.3
Bus. (H)	60493.7	29362.5	22655	107179
Year	2012.5	4.04	2006	2019
Observations	196			

Notes: Summary statistics for the variables of interest by state. California data is found in Table C1.

m counties adjacent to county i in year t, A_i is the land area in county i in square miles (100s) and $\sum_{j=1}^{m}(A_j)$ is the total land area in the m counties adjacent to county i.

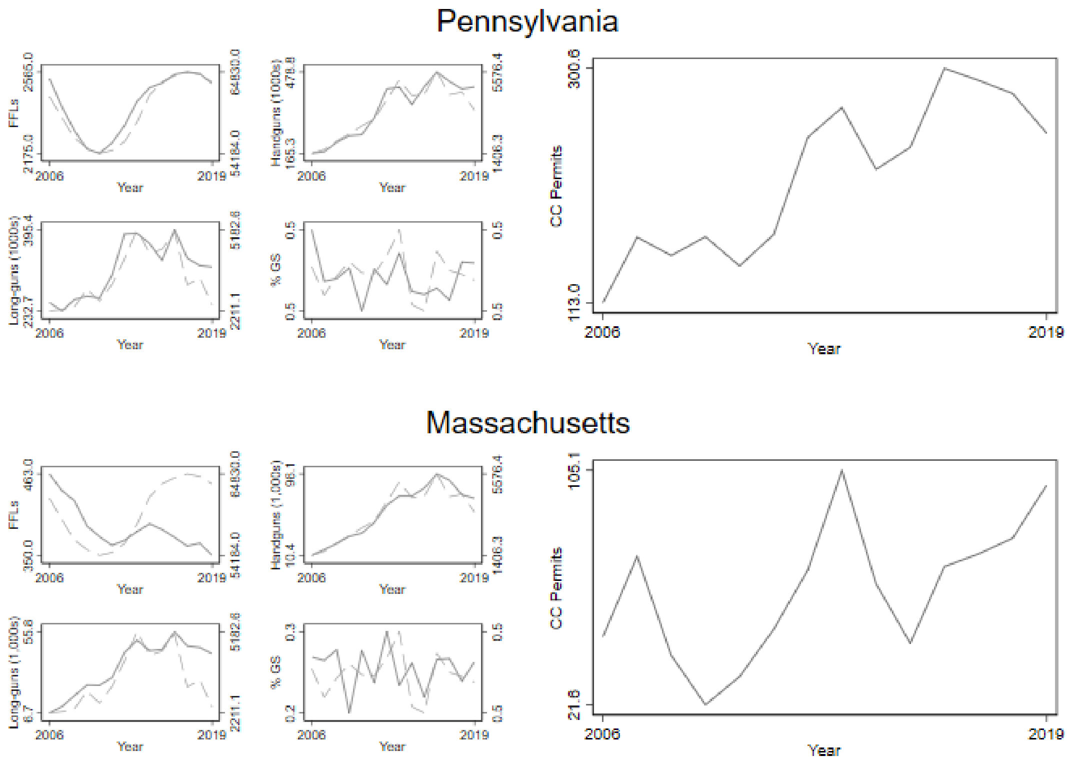
Figure 5: Gun Dealers in and around Major US Cities (2020)



Notes: Gun dealer by zip code in around large US cities. From top left to bottom right: Minneapolis (bottom right in Hennepin County), Chicago (right side of Cook County), Detroit (upper right of Wayne County), Philadelphia (all of Philadelphia County), Boston (all of Suffolk County), and Kansas City (left side of Jackson County).

The motivation for grouping counties in a halo measure is found in Figure 5 which illustrates the number of FFLs in the county and zip codes around a handful of large cities in the United States. With this, the main benefit of the area measure of FFLs per mile is apparent: it takes into account that just because there are no FFLs in a particular county, it does not mean that there are no FFLs nearby. For example, some zip codes around Philadelphia County (bottom left) have more dealers than Philadelphia County itself. The second benefit is that unlike state-level measures (e.g., background checks and hunting permits) the measure can cross state lines (e.g., the inclusion of Burlington, Camden, and Gloucester counties which are all in New Jersey). Even though federal law prohibits the purchase of handguns in one state by the resident of a different state (unless first transferred to a FFL in the buyer's state of residence, who is responsible for making sure the purchase complies with the buyer's state laws), research shows that gun trafficking across state lines is common, particularly between nearby states (?). A third benefit of this measure is that it is tracked by a centralized authority (the ATF). This is important because it means that it is consistently measured across states unlike, say, concealed carry permits which mean

Figure 6: Trends in Gun Measures (2006-2019)



Notes: From top left to bottom right for the left-hand panels: FFLs (dealer and pawn license holders), reported handguns sold, long-guns sold, and % of suicides involving a gun. The dashed line corresponds to national trends. The solid line is the specific state only. The top panel uses data from Pennsylvania. The bottom is Massachusetts. Note to make the data from yearly ATF reports compatible with the J&R data, we lead county-based counts by one year. This is because the original counts are from (in most cases) January totals (see **?** for more details). Newly issued concealed carry trends are found in the right-hand side panels (1,000s of permits issued). Similar trends for California are found in Figure C1.

different things in different states due to legislative differences.

Trends in the total number of gun dealers, reported gun sales (both handgun and long-gun), the %GS, and homicides for Pennsylvania (top panel) and Massachusetts (bottom panel) are found in Figure 6 alongside their national counterparts. Pennsylvania's FFLs trend matches the national trend, with FFLs bottoming out around 2010. This is not the case for Massachusetts which only had a slight recovery after bottoming out before falling again around 2014. Local sales of handguns correspond to national manufacturing trends reported by the ATF for both states while long-gun sales match national trends up until around 2016.[18] The percentage of suicides involving a gun also matches national trends for Pennsylvania but less so for Massachusetts. Figure 6 also presents trends in newly issued concealed carry permits for the two states (1,000s).

[18]Data is found here: https://www.atf.gov/firearms/docs/report/2021-firearms-commerce-report/download

4 Results

We break our results into sections. We begin by discussing results using standard panel analyses, and describe why land-based measures tend to perform better. We then show a drawback of using measures that are tied to a specific county using a database of gun thefts. Finally, we close by presenting non-causal associations between gun homicides and the different measures of gun prevalence.[19]

4.1 Panel Analysis

We start by estimating the various proxy measures, using the lagged gun sales (handgun and long-gun) in county i in year t as the primary explanatory variable, with a series of linear panel regressions.

The basic model is:

$$P_{i,t} = \beta_0 + \beta DM_{i,t} + \beta X + \epsilon_{i,t} \tag{2}$$

where $P_{i,t}$ is a proxy measure of gun prevalence in county i in year t, $DM_{i,t}$ is a direct measure of gun prevalence, and X is a vector of county level demographic variables. The direct measures are handgun sales, long-gun sales, and the number of concealed carry permits issued. The proxy measures are %GS, FFLs PC, FFLs PM, FFLs, FFLs PC (H), FFLs PM (H), and FFLs (H). Also, when using concealed carry permits to estimate proxy measures, we explore the relationship between concealed carry permits and the two direct measures (handguns and long-guns).[20]

The control variables include county population, % Black, % male, and population density to account for changes in local demographic factors that could affect the demand for guns. We also control for business establishments per mile and the unemployment rate to account for local economic conditions, since both gun sales and the opening/closing of gun dealers could be correlated with changes in the local economy.[21] Standard errors are clustered at the county level. All models include county fixed effects and year fixed effects. We estimate the proxy measures using the direct measures with data for each state individually and pooled sample. This gives us 21 separate estimates for handgun sales, 21 separate estimates for long-guns sales, and 27 separate estimates for those involving concealed carry permits. We present results, based on the pooled sample, graphically in Figure 7; point estimates, for each of the samples, can be found in the Appendix.[22] Estimation results without control variables are very similar (Tables B4, B5, and B6 in the Appendix).

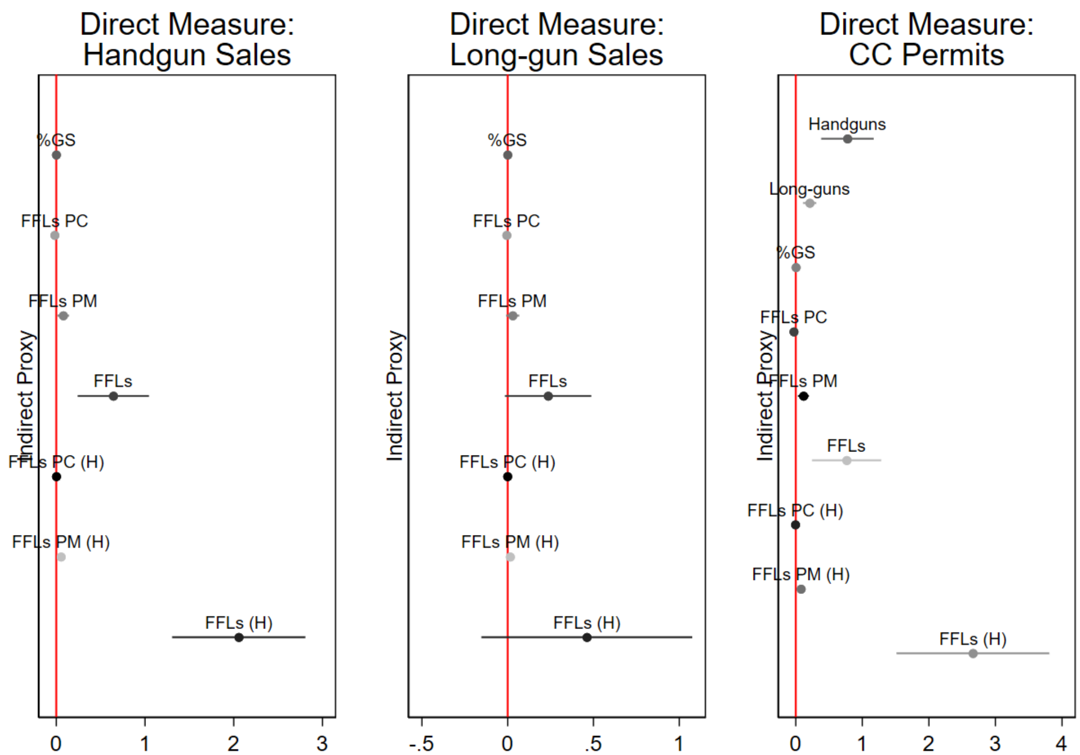
[19] We also examine simple correlations of the different measures and we run a "horse race" in which we predict the change in gun sales (concealed carry permits issued) in two (four) states using coefficients derived from models that were generated with data from Massachusetts and Pennsylvania. These results and discussion are found in the Appendix.

[20] Sales are technically lagged two years to account for differences for when the measures are taken (sales are end of the year and FFL counts are at the start of the year) and to account for FFLs opening in areas where sales are high.

[21] We also run these regressions without control variables, which are found in Appendix B.1.

[22] Specifically, Table B1 is handgun sales, Table B2 estimate is long-gun sales, and Table B3 estimates concealed carry permits. Samples are as follows: Pennsylvania only (top panel in Tables B1, B2, and B3), Massachusetts only (middle panels in the same tables), and a pooled sample made up of Pennsylvania and Massachusetts counties (bottom panel).

Figure 7: Estimated relationship between Indirect Measures of Gun Prevalence and Direct Measures



Notes: Fixed effects regression results. Each model contains county and year fixed effects. The sub-figure title indicates the direct measure of guns used. Standard errors are clustered at the county. All models control for population, the unemployment rate, the percentage of the county that identifies as Black/male, the population density, and the business density. Point estimates using the California data are found in Table C2.

We begin with the first panel in Figure 7 which presents results pertaining to handgun sales (i.e., the dependent variable is handgun sales). Here we find a significant and positive relationship between handgun sales and FFLs PM, FFLs, FFLs PM (H), and FFLs (H).[23] Long-gun results are presented in the middle panel of Figure 7. In each of these models, the outcome variable is long-gun sales. Here we find that none of the proxy measures are correlated with the change in yearly long-gun sales. Overall this suggests that FFLs PM (H), and FFLs (H) do the best job tracking the year-to-year variation in handgun sales. All measures do poorly when estimating long-gun sales. Point estimates using the California data are found in Table C2.

Point estimates for the relationship between concealed carry permits, gun sales, and the other proxy variables are found in the right panel of Figure 7. The variable of interest in each of these regressions is the number of concealed carry permits issued in county i in year t (or CC permits in the table). The outcome variables are guns sold (handgun and long-gun), %GS, FFLs PC, FFLs PM, FFLs, FFLs PC (H), FFLs PM (H), and FFLs (H). In the pooled sample, there is a significant and positive relationship between gun sales and concealed carry permits.[24] This suggests that concealed carry permits are closely related to gun sales and are consistent with the correlations shown in Table A2. FFLs PC also has no significant relationship with concealed carry permits. FFLs PM (and FFLs) are positively correlated with the number of concealed carry permits issued but the relationship is only statistically significant in the Pennsylvania and pooled samples. FFLs PC (H) does not have a significant relationship with concealed carry permits. FFLs PM (H) and FFLs (H) are both positively correlated with the number of concealed carry permits issued in the pooled sample.[25]

It is particularly worth noting that %GS has no significant relationship with any direct gun measure. This is consistent with **?**, who showed that changes in the %GS did not correlate with trends in direct gun measures (survey data) over time despite showing a significant relationship cross-sectionally. With three different—and arguably better—direct gun prevalence measures, we also no relationship between the %GS and gun prevalence in a longitudinal setting. This provides further evidence that using the %GS is only appropriate in cross-sectional analyses.

4.1.1 Why do the Land-Based Measures Perform Better?

Overall we find population-based measures of gun prevalence perform quite poorly while the land-based measures and raw counts do comparatively better. From a theoretical perspective, this is explained by the fact that the main variation in the costs of acquiring a firearm—price competition between dealers and the non-monetary costs of finding and procuring the firearm—are primarily influenced by one's geographic proximity to a gun

[23] Statistical significance of these relationships varies depending on the sample. For example, FFLs PM (H), and FFLs (H) are significant in all three samples while FFLs PM is only significant in the pooled sample. This seems to be driven by sample sizes. The magnitude of the relationships are similar in all samples.

[24] This is also the case in each of the sub-samples.

[25] However, the relationship between FFLs PM (H) is not statistically significant in the Massachusetts sample. The lack of a significant relationship between concealed carry permits/handgun sales and the FFL-based measures in the Massachusetts sample is likely due to Massachusetts having roughly a fifth of the counties that Pennsylvania has and the lack of gun dealers in Boston.

dealer. Because of this and differences in types of customers, gun dealers in close proximity to each other are often quite different types of dealers than those that are not. This is practically illustrated in Figure 8: counties with a high number of gun dealers per person have dealers who sell fewer guns per FFL. At the same time, counties with a high number of FFLs per mile have dealers who sell more guns per FFL (particularly, handguns) on average.

For instance, in 2019 the average number of handguns sold in counties in the *top* quartile of gun density (in terms of gun dealers per mile) was nearly 12 thousand whereas counties in the *bottom* quartile sold only 2 thousand on average in Pennsylvania. Similarly, counties in the *bottom* quartile of gun density (in terms of dealers per capita) on average had about 10 thousand handguns sold by dealers in their borders; counties in the *top* quartile had only 1.6 thousand in sales on average.

This result shows that gun dealers in urban areas are qualitatively different from those in rural areas; they sell more guns than their rural counterparts. This pattern is not unique to a specific year and similar comparisons for all years in the sample can be found in Tables B7 (handguns) and B8 (long-guns). Results in these tables (found in the Appendix) also suggest that the make-up of guns sold in rural areas is quite different from what is sold in urban areas. Gun dealers in rural areas tend to sell an equal amount of handguns and long-guns while gun dealers in urban areas sell about twice as many handguns as they do long-guns.

4.1.2 Gun Migration

A second benefit of FFL-based measures of gun prevalence is that they can be used to correct for the porous nature of borders. To illustrate the importance of this, we use the recovered gun database made public by the Pennsylvania State Attorney General.[26] This database records "crime-guns"—guns that were recovered during the investigation of a crime—recovered in the state of Pennsylvania.[27] Among the many variables kept in this database is the county of the dealer the crime gun was traced to and the county the gun was recovered.

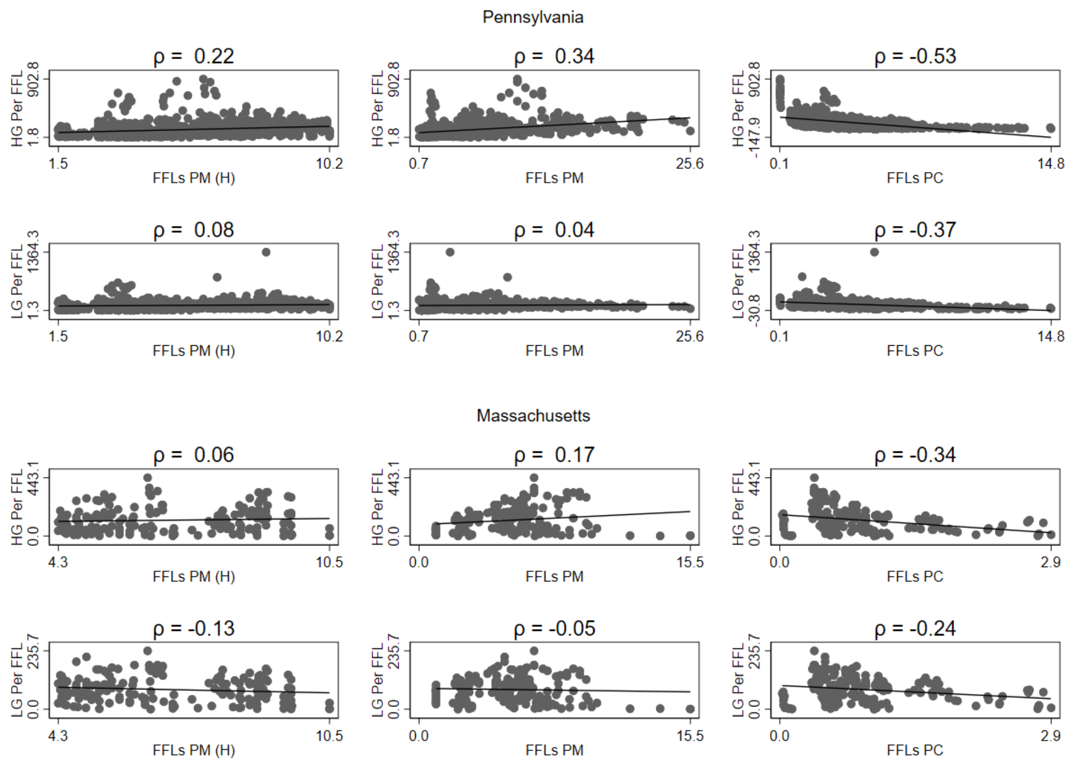
Around 166,000 guns are reported to be traced in this database. We focus our analysis on guns that were traced to a Pennsylvania gun dealer, were recovered in Pennsylvania and were recovered between 2003 and 2019. As such, 22,207 recovered guns are dropped due to them being recovered before 2003, 313 are next dropped because they were recovered outside of PA, another 62,188 are dropped due to being traced to an out-of-state dealer, 98 are dropped because the recovery variable indicated a non-existent county (e.g., United States). Finally, 5,104 more are dropped due to the trace failing (e.g., dealer county was "unknown"). This leaves us with 75,759 traced firearms.[28] Out-of-state dealers are dropped due to the trace data being incomplete and/or the trace linking the gun to a manufacturer (e.g., Browning, Colt, etc.). This linking was initially done by linking the dealer's phone

[26]Data is found here: https://www.attorneygeneral.gov/gunviolence/pennsylvania-gun-tracing-analytics-platform/

[27]The gun may or may not be related to the crime. Also, note that recovery depends on participation and the focus of the individual agencies.

[28]Figures B1 and B2 indicate the number of guns reported for each county in Pennsylvania. These figures also indicate the total number of guns sold in the county.

Figure 8: Guns Sold per FFL vs FFLs Per Mile and FFLS Per Person



Notes: Correlations between gun sales per FFL and gun dealers per mile and gun dealers per 10,000 people. The line corresponds to the OLS regression line. From top left to bottom right: gun dealers per 100 (county i and counties adjacent to i) miles vs. handguns sold per FFL, gun dealers per 100 miles vs. handguns sold per FFL, gun dealers per 10,000 people vs. handguns sold per FFL, gun dealers per 100 (county i and counties adjacent to i) miles vs. Long-guns sold per FFL, gun dealers per 100 miles vs. long-guns sold per FFL, and gun dealers per 10,000 people vs. long-guns sold per FFL. The top panel uses data from Pennsylvania. The bottom is Massachusetts. Rows 1 and 3 correspond to handguns per FFL. Rows 2 and 4 are long-guns per FFL. Above each graph is the Pearson correlation coefficient. Similar trends for California are found in Figure C3.

number in the recovery database with ATF records. This feature in the public database has been lost but it was noted and used by one of the authors before the feature was dropped.[29]

In Figure 9, we present a graphical summary of the dealer-recovery relationship for guns that were recovered in Pennsylvania between 2003 and 2019 and had a successful trace (i.e., the dealer who sold the crime gun was successfully identified)—roughly 75,000 guns. In Figure 9, the x-axis is the county the gun was recovered in and the y-axis is the county where the dealer who sold the gun is located. Marker size corresponds to the pair's size. First, we note that a substantial portion of guns are recovered in the county they were sold, but it is not universal. Overall, about 54 % of recovered guns, that could be traced, were recovered in the same county they were traced to - which is indicated by the 45° line in Figure 9.

Examining the crime-related guns that were recovered in a different county than the one they were traced to is less straightforward because there are 4,442 possible pairs after accounting for the diagonal in Figure 9. To address this, we focus on the pairs (recovery-trace relationships) that appear more than 75 times which is about two-thirds of the guns that did not get traced to the same county they were recovered. The resulting pairs of interest are found in Figure 10. The y-axis in Figure 10 shows common county pairs, with the first county label being the county that the crime gun was traced to and the second being the county where the gun was recovered. The x-axis is the number of times that county pair appeared. Dark shaded bars indicate the counties share a border.

The top four pairs are all consistent with the halo measures. These guns (about 14,000) were all sold in counties adjacent to Philadelphia [Allegheny] County (Delaware, Montgomery, and Bucks [Westmoreland]) and recovered in Philadelphia [Allegheny] County. Similar sorts of patterns are observed as we move down the list with some caveats. First, guns recovered in Philadelphia come from all over the state but usually come from adjacent counties or nearby counties (e.g., Berks and Chester). Second, when the measure fails, it usually does so in a predictable way (e.g., Berks and Dauphin counties are not adjacent but are geographically close to each other). Overall, we interpret this as evidence in favor of the "halo" measure: guns cross county lines so any measure of gun density should not focus on strict geographic boundaries.

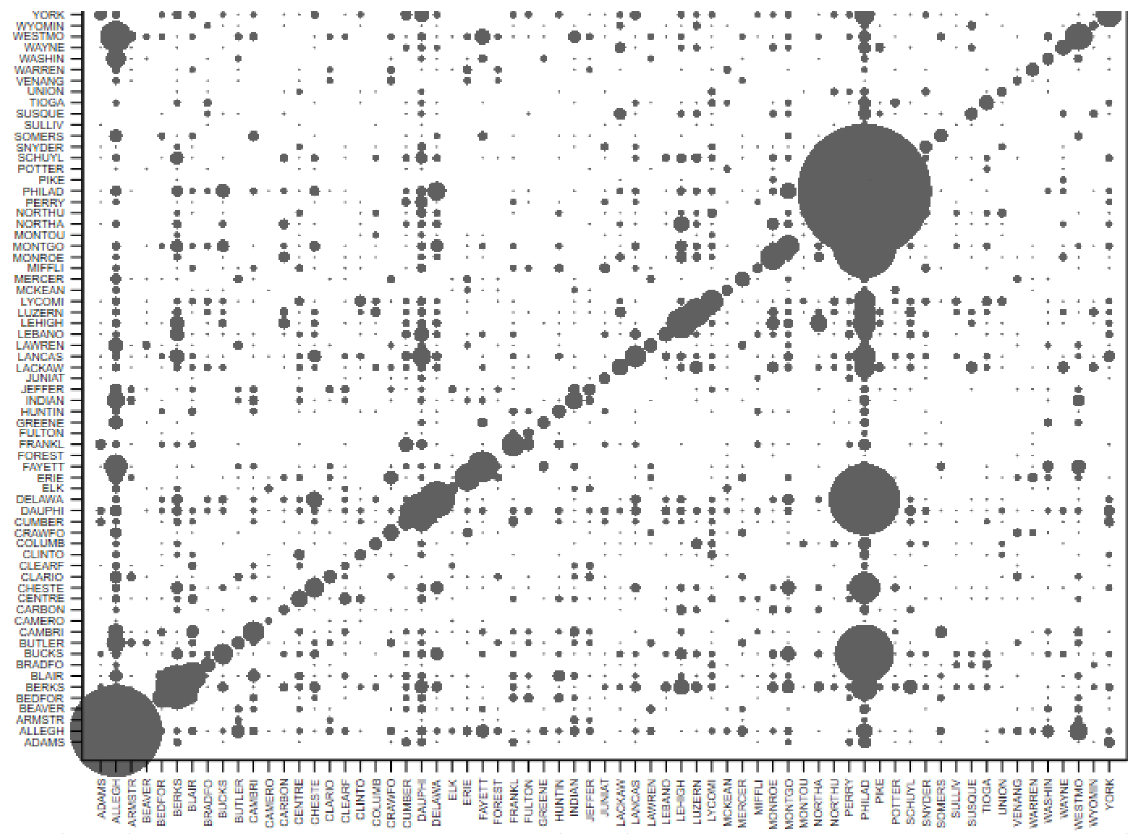
If we assume that gun sales are a good indicator of the flow of firearms into a geographic area, then the results of this section, combined with the results of the previous section, suggest that FFLs per mile predict sales better than the most common gun prevalence measure (%GS). This suggests that the halo measure is the best current proxy for gun prevalence. This is particularly true if the researcher needs data that covers the entire United States and/or is available at a finer geography than the state or national level – which would preclude the use of survey data, National Instant Criminal Background Checks (NICS), and hunting permits. The added benefit of this measure is that it implicitly picks up guns acquired through theft and black/gray markets as crime guns generally stay local.

4.2 Gun Prevalence Measures and Homicide

In previous sections, we provide significant evidence that the halo measure of FFLs per mile best captures the variation in new gun prevalence. However, this is of limited importance

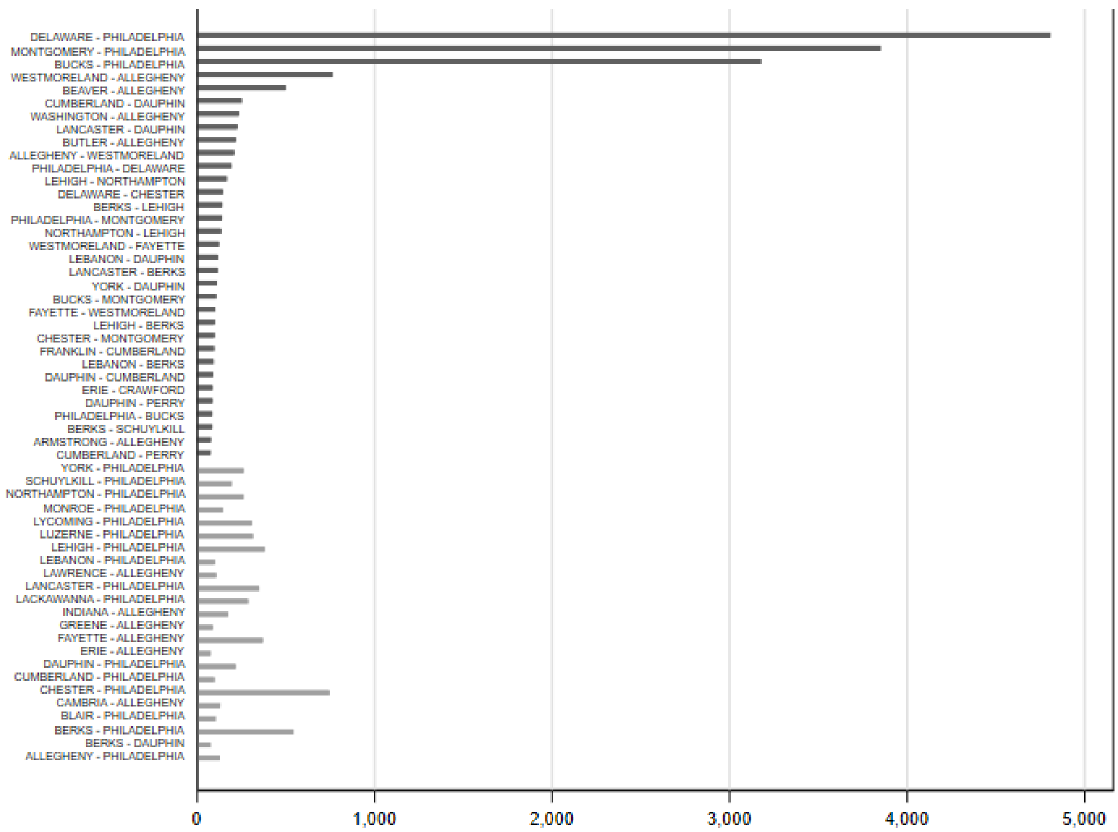
[29] http://phlcouncil.com/wp-content/uploads/2022/01/100-Shooting-Review-complete.pdf

Figure 9: Gun Recovery and Trace Results



Notes: County of recovery (x-axis) vs the county the gun was traced to (y-axis). Marker size corresponds to the pair's size (e.g., the most common recovery-trace relationship is Philadelphia County - Philadelphia County).

Figure 10: Common Trace - Recovery Pairs



Notes: Common pairs not including same county trace and recovery pairs. y-label corresponds to the pair. The first county is the county to which the gun was traced to (i.e., dealer location) and the second county is where the gun was recovered. Dark-shaded bars are county-adjacent pairs.

unless we can also show that using the "best" proxy is important for understanding how gun prevalence is associated with important gun-related outcomes. To do so, we estimate gun homicides on the various gun proxy measures. Before proceeding we want to make it clear that this is an exercise to show the heterogeneity in associations and that these estimates should *not necessarily* be taken as causal—although we do assume a 3-year lag to account for stolen and black/gray market guns being the primary sources of crime guns. We want to avoid making causal statements for two reasons. First, Pennsylvania and Massachusetts are above average in terms of gun control. For example, Everytown, a pro-gun control group, ranks Pennsylvania and Massachusetts at number 15 and number 6 in terms of gun laws (i.e., the lower the ranking the stricter). Thus these estimates would not be representative of the United States as a whole. For example, the marginal effect of a gun in Massachusetts is probably different from the effect in the rest of the United States. Second, each of these measures would require a different identification strategy. While, in principle, since they are all attempting to measure the same latent variable, a single identification approach should work for all, this may not always be true practically.

We estimate the following model,

$$E[GH_{i,t}|X_{i.t,}, GP_{i,t}] = exp(\beta_0 + \beta_1 GP_{i,t-3} + \beta_{\neq 1} X_{i,t}) \tag{3}$$

where $GH_{i,t}$ is the number of gun homicides in county i in year t, $X_{i,t}$ is a vector of county level control variables (population, % Black, poverty rate, and % male), which where chosen based on the consistency with prior literature and the availability of the data at the county level (**???**).

Gun prevalence is lagged three years in past ($GP_{i,t-3}$) to avoid the most obvious reverse-causality concerns (individuals purchasing guns *in response to* a recent increase in homicide rates) and to account for the time it takes for a legally purchased gun to move to the underground gun market. The three-year lag is not arbitrary. Figure 11 show box plots for the time between the legal sale of a gun and its eventual recovery in connection to arrests for various crimes using the same recovered gun database discussed in Section 4.1.2. Critics of a three-year lag might note that the average age of a firearm used to commit a crime is between 10–15 years old (**?**), which is consistent with our Pennsylvania data that shows an average time to crime of just under 10 years (solid red line in the figure). However, this statistic is somewhat misleading. The box plots in Figure 11 show that the average is the result of highly right-skewed distributions, and that the median (solid black line in each box) and modal time to crime is much lower. Given that crimes are likely committed with many of these firearms before they are recovered in a criminal arrest, the actual time to crime is even lower, which is how why we use a 3-year lag (dashed red line in the figure).

We consider nine measures of gun prevalence: proportion of gun suicide (%GS), concealed carry permits issued (LTC), handgun sales (HG), gun dealers (FFLs), gun dealers per capita (FFLs PC), gun dealers per mile (FFLs PM), gun dealers in a county area (FFLs (H)), gun dealers per capita in a county area (FFLs PC (H)), and gun dealers per mile in a county area (FFLs PM (H)). We present estimation results using the raw gun prevalence measure as well the natural log of the gun prevalence measure—with the interpretation of the former being a semi-elasticity and the latter being an elasticity.[30] Coefficient estimates

[30] As a reminder, note the interpretation of a semi-elasticity (elasticity) is a one unit (percent) change in

Figure 11: Time from Legal Gun Sale to Recovery After Criminal Use

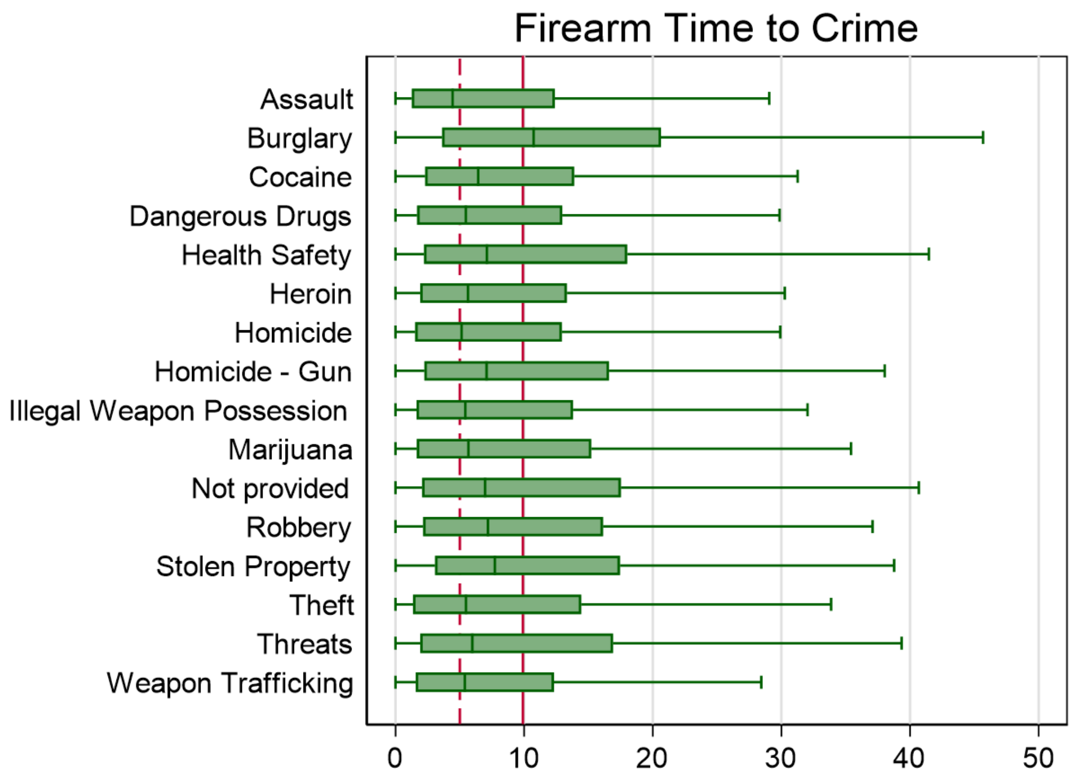
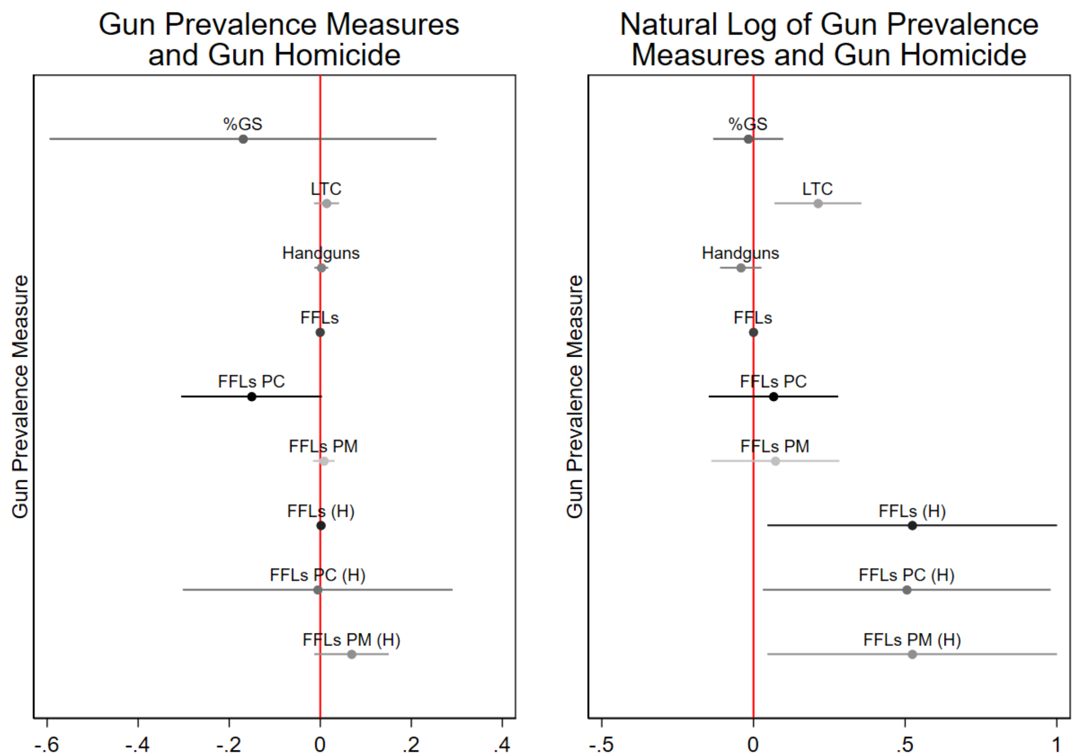


Figure 12: Gun Prevalence Measures and Homicide



Notes: Estimated relationship between gun prevalence measures and gun homicide. All models are fixed effects Poisson with county clustered standard errors. Other explanatory variables include population, % Black, % male, and poverty rate. Data is from Pennsylvania and Massachusetts and is from 2006-2019. Similar estimates including the California handgun data are found in Figure C5.

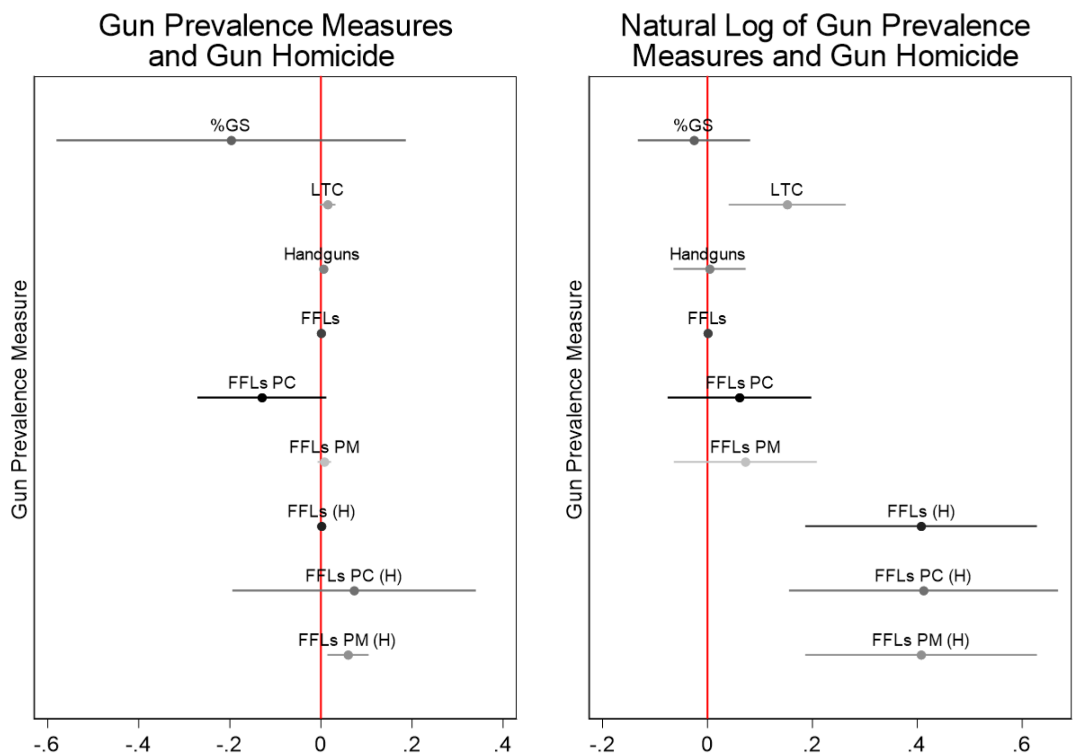
on the different measures of gun prevalence are found in Figure 12 and full results are found in Table B9 of the Appendix. All models are estimated via fixed-effects Poisson regression with standard errors clustered at the county level and use data from 2006-2019.

The left-side panel of Figure 12 presents the coefficient estimates using the raw gun prevalence measure while the right-hand panel uses the natural log of the gun prevalence measure. Estimates not including any control variables are found in Figure 13 and are very similar to the point estimates with controls.[31] The proportion of gun suicides has no significant relationship with gun homicides, which is expected because the proportion of gun suicides is not highly correlated with LTC permits or gun sales. While this might seem surprising when compared with **?**, one needs to remember **?** used only a handful of most populated counties while here we are using every county in Pennsylvania and Massachusetts. FFLs PC, FFLs PM, and FFLs all have no significant positive relationship

the explanatory variable increases the outcome variable by the percent indicated by the coefficient.

[31] This suggests that the county fixed effects are likely absorbing the majority of the between county differences that would affect these outcomes and that any unobserved determinants of homicide that are changing over time are doing so similarly between counties.

Figure 13: Gun Prevalence Measures and Homicide (No Control Variables)



Notes: Estimated relationship between gun prevalence measures and gun homicide. All models are fixed effects Poisson with county clustered standard errors. Data is from Pennsylvania and Massachusetts and is from 2006-2019.

with gun homicides and FFLs PC has a negative relationship—although the relationship is positive and not significant in estimates using the log transformation. This result is not surprising. These county measures had a weak and inconsistent relationship with handgun sales and growth in FFLs PC was negatively associated with handgun sales—the most common type of crime gun.

Estimation results suggest no significant relationship between handgun sales and gun homicide. However, given the strengths and weaknesses of each of the measures this result is, ex-post, not surprising. First and foremost, the issue with gun sales is that the county where the gun is sold is often different from where the owner lives. This will particularly be a problem in more urban counties (e.g., Figure 5) where gun dealers locate outside of urban centers. Moreover, a sale is very different than a gun moving around in public. An individual may walk around in public with a gun but they are unlikely to carry more than one; so additional sales are not necessarily changing public exposure and could represent a growing collection.

LTC permits (which have a positive relationship with gun homicides in both specifications) on the other hand do not have the same drawbacks. Generally, increases in the number of LTC permits in a given county implies an increase in the number of handguns moving around in public—making them more likely to affect the public whether by owner use or theft. Moreover, unlike handgun sales, these weapons are linked to the county that the permit holder lives in rather than the county where the gun was sold. This partly mediates the biases caused by FFLs located outside of major urban centers (again e.g., Figure 5). In the same vein, the relative "success" of LTC permits should not overshadow the success of the halo measures—particularly FFLs PM(H). This measure has all the benefits LTC permits due to its nature (i.e., being a local area) but also allows for spillovers across county lines that may be due to circumstances like travel or theft (e.g., Figures 9 and 10).

It is worth noting that none of the gun prevalence measure are statistically significant when estimated as semi-elasticities (although FFLs PM (H) is very close). This is likely a combination of the relatively small sample size and the differing assumptions of these models. Using the raw gun prevalence measure in the regression (as opposed to the natural logarithm of that measure) assumes a one-unit change in the measure has the same effect across all counties. Thus, for example, this model implicitly assumes that an additional FFL in a county with 47 current FFLs has the same impact on homicides as an additional FFL in a county with more than 500 current FFLs (this reflects the true variance of our sample), which is likely an unrealistic assumption. Using the natural log of the gun prevalence measures in the regressions instead assumes that the effect on homicides is consistent across *proportional* increases in gun prevalence—a 10 percent increase in FFLs, for example. Thus, it is advisable to estimate coefficients as elasticities—particularly when the panel size is small and there high variance in the explanatory variable across units (counties in our case).

5 Discussion & Conclusion

We compare existing indirect measures of gun prevalence to reported gun sales in Pennsylvania and Massachusetts. We find the most common measure of gun prevalence, the percentage of suicides involving a gun is not associated with gun sales or concealed carry permits. The same pattern is true for the number of gun dealers per capita. In contrast, measures of gun prevalence (more specifically handguns) involving gun dealer counts or gun dealer counts per mile are positively correlated to gun sales and concealed carry permits—suggesting area gun dealer density is the most appropriate measure of gun prevalence at the county level.

Concealed carry permit data is far more available than gun sales data, highly correlated with gun sales, and these permits are tied to the county of residence. Given this, and the results presented, it is tempting to come to the conclusion that concealed carry permits are the best available measure of gun prevalence. This is probably not true. First, as with county sales, using concealed carry permits as a measure of gun density does not completely mitigate the arbitrary lines problem. The second problem, which is more of a data-cleaning problem, is inconsistency in reporting; specifically in terms of timing/published output.[32] Third, there are problems relating to the differences in state laws relating to concealed carry permits. At the extreme end, we have states with no concealed weapons permits (which would imply no gun sales if this measure was used) and, on the other, we have states with shall-issue laws which probably map very well to gun sales. This problem is made even worse as more states move to constitutional carry.

There are also other smaller problems with both concealed carry permit and gun sales data. First, both datasets likely contain reporting errors.[33] A final problem, related to sales data in particular, is due to sales being reported to the government in the first place. There are many legal/illegal gun sales and thefts (both secondary "markets") that are not reported (although primary and secondary market transactions are likely correlated). Consequently, both measures likely understate the true changes in gun prevalence. Research using gun sales and transfer data continues to be promising, however. **?** recently linked the universe of legal gun sales and transfers to voter registration data and death certificate records, which allows researchers to study the effect of gun access at the individual level for more than 12 years for nearly 30 million California residents. This data has already produced some interesting results with regard to the link between household firearm access and homicide (e.g. **?**).

For many researchers, though, the FFL-based measures of gun density may be the best proxy for gun prevalence. Empirically, this measure is correlated with estimates of household firearm ownership (at the state-level), handgun sales, and concealed carry permits, and variations in each of these maps to changes in the others. Therefore, if we see an increase in FFLs in a given area we can be reasonably certain there was a local increase in gun prevalence. The next benefit is that this measure is kept at the federal level—so it is consistently reported. The rules of setting up an FFL are mostly the same across states and the timing of reporting (usually monthly) does not differ across states. Given that the lists contain addresses, the arbitrary lines problems can also be addressed. While estimates

[32]Some states report total active permits while others report new permits. These cannot be directly compared. Further, states may report based on end-of-year counts or the end of the fiscal year.

[33]E.g., the incorrect FFL count in Philadelphia county that was previously discussed. We also note a clear reporting error in the 2019 Annual Legislative Report published by the Louisiana Department of Public Safety. These reports give the number of concealed weapon permits by parish and year. However, in 2019 there was an obvious error. On page 65, the report indicates there were 11,456 original five-year permits issued but the actual parish counts (on page 68) indicate counts that would make the 11 thousand figure impossible (e.g., Jefferson Parish had 11,552 permits issued). The report can be found here: http://www.lsp.org/pdf/2019_CHP_Annual_Legislative_Report.pdf

of HFR might be somewhat preferable this data is only available at the state level which limits its utility. There are however three main problems with FFLs. First, with the FFL list published by the ATF, we have no idea the number of guns sold by each FFL (though some inference can be made based on the name/location of the FFL). Second, we have no idea of the kinds of guns sold (though again some inference can be made based on the name/location of the store). Last, the FFL land density-based measures perform best when proxying the variation of handgun sales; they do no better than the alternatives when applied to long-guns, which explains why this measure has a positive relationship with gun homicides. Future work will explore ways to lessen these problems.

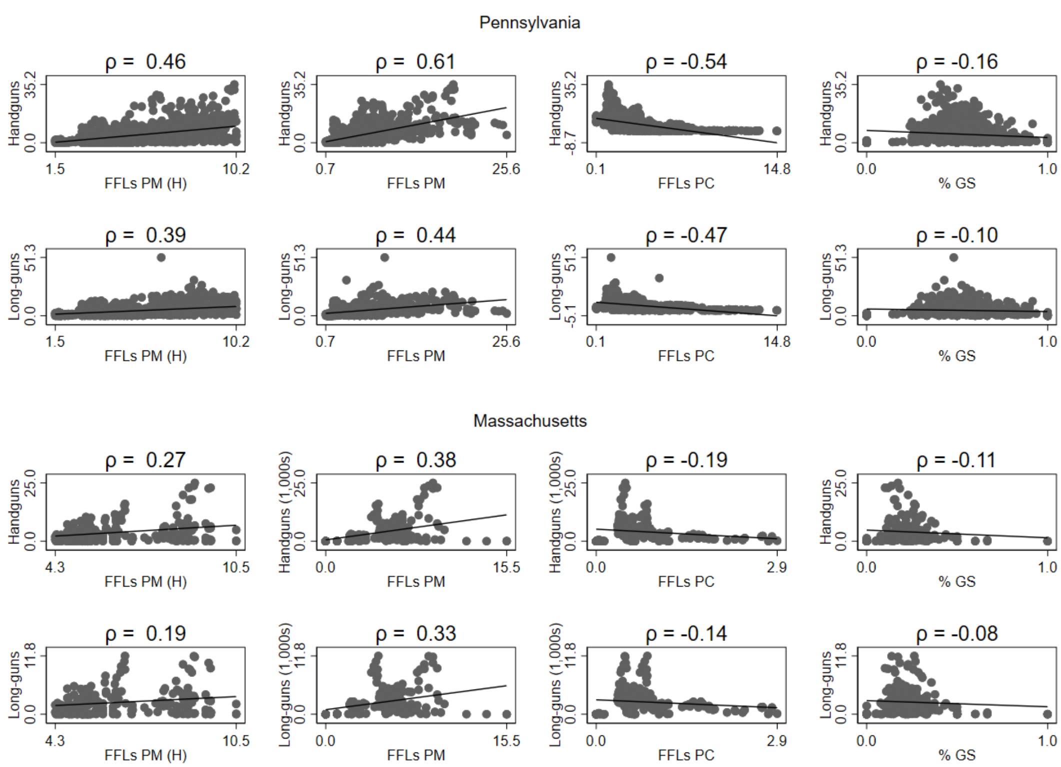
One major limitation of all the analyses perform in this study is that these results may lack generalizability due to our gun sales data only coming from two states, which are not likely representative of the US as a whole. It is worth noting that **?** used the percentage of gun suicides and all FFL-based gun prevalence measures (all measures used in this study minus the gun sales and conceal carry data) to estimate the effect of gun prevalence on homicide using county-level data from all 48 contiguous US states and find very comparable estimates (in constant elasticity models) to the estimates found in this study for Massachusetts and Pennsylvania. Nonetheless, the relationship between these gun prevalence proxy measures and gun sales and conceal carry permits should be examined with this limitation in mind.

Another limitation of our study is that we only examine the relationship between gun prevalence and homicide and not a broader set of violent and/or gun-related crime. This is important as studies show evidence that the effects of gun prevalence may vary significantly by crime type (e.g. **??**). Future work could extend our analysis to different types of crime to examine whether the benefits of using our land-based FFLs measure hold for crimes beyond gun homicides.

A Simple Correlations

Here we document the correlation between the indirect measures of gun prevalence with gun sales. Scatter plots overlaid with linear regression lines are found in Figure A1. Only two indirect measures of gun prevalence positively correlate with gun sales (both long-gun and handgun): FFLs PM and FFLs PM (H). Areas with a high number of gun dealers per capita (per 10,000 people in the graphs) have lower gun sales. The percentage of gun suicides is also inversely correlated with gun sales. This relationship occurs in both Pennsylvania and Massachusetts.

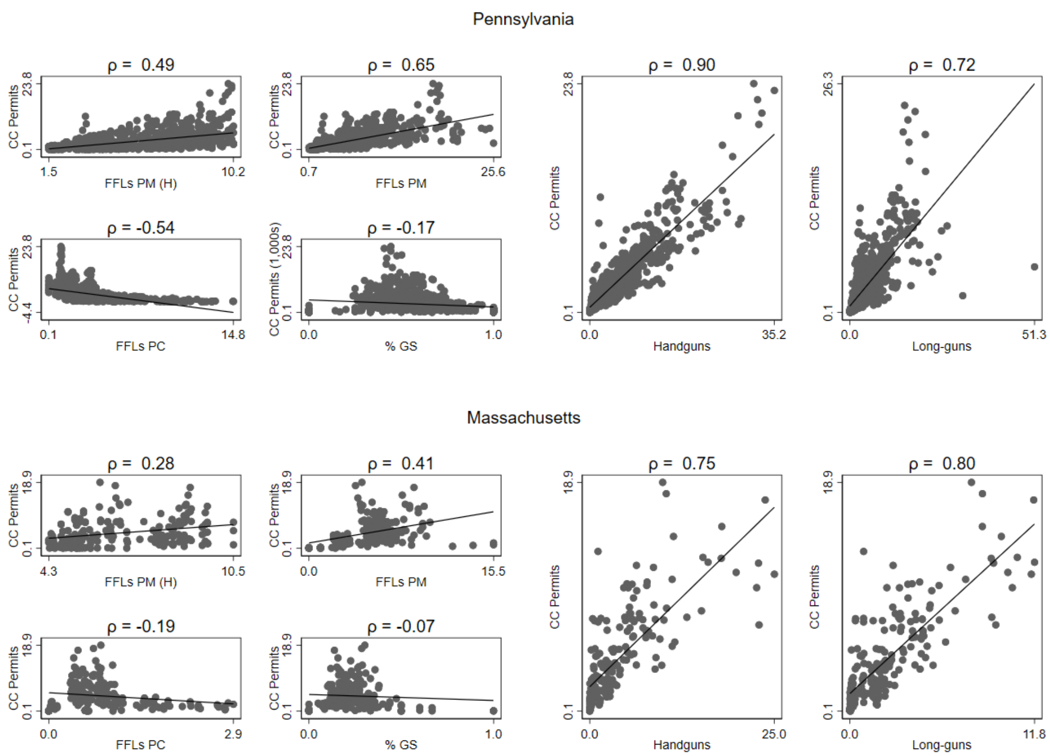
Figure A1: Simple Correlations of Gun Proxies and Reported Gun Sales



Notes: Correlations between gun sales and various measures of gun prevalence. The line corresponds to the OLS regression line. The top panel uses data from Pennsylvania. The bottom is Massachusetts. Above each graph is the Pearson correlation coefficient. Similar trends for California are found in C2.

Scatter plots of each of the indirect gun measures (and gun sales) and concealed carry permits are found in Figure A2. As in Figure A1, we find a positive correlation between concealed carry permits and FFLs PM and FFLs PM (H) as well as a slight negative correlation between concealed carry permits and FFLs PC and %GS. This relationship occurs in both Pennsylvania and Massachusetts. We also note a positive correlation between concealed carry permits and handgun/long-gun sales in both states.

Figure A2: Simple Correlations of CC Permits, Gun Proxies, and Reported Gun Sales



Notes: Correlations between concealed carry permits, sales, and various measures of gun prevalence. The line corresponds to the OLS regression line. The top panel uses data from Pennsylvania. The bottom is Massachusetts. Above each graph is the Pearson correlation coefficient.

A.1 Comparing "Dirty" Forecasts

Overall, FFLs PM (H) has the most significant relationship with handgun sales while % GS is not correlated with sales. As a final test, we forecast gun sales (i.e., long-gun sales plus handgun sales) and newly issued concealed carry permits using %GS and FFLs PM (H). To generate coefficients, we estimate the following first difference model:

$$\widehat{DM_{i,t} - DM_{i,t-1}} = \beta_0 + \beta_1(IDM_{i,t} - IDM_{i,t-1}) \tag{4}$$

with pooled OLS using the data from Pennsylvania and Massachusetts. $DM_{i,t}$ is gun sales or newly issued concealed carry permits in county i in year t and $IDM_{i,t}$ is the gun density proxy (%GS or FFLs PM (H)) in county i in year t. We then apply these coefficients to data from other states that also have yearly county gun sales/concealed carry permit data.

We begin with gun sales. As of the original writing, two states have made at least some county gun sales data available to us: Maryland and Utah.[34] Unfortunately, the data reported by these states do not differentiate between handguns and long-guns. Therefore, to make the data compatible, we combine handguns and long-guns in the Pennsylvania and Massachusetts data and then estimate the model above. The resulting coefficients are $\beta_0 = .796[p < 0.001]$ and $\beta_1 = -.041[p = 0.930]$ using %GS and$\beta_0 = 0.263[p = 0.032]$ and $\beta_1 = 2.87[p < 0.001]$ using FFLs PM (H). We now apply these coefficients to Maryland (2017-2020) and Utah (2008-2020) and compare the predicted sales to the actual sales. Results are found in Figure A3 which depicts a scatter plot of the change in gun sales (y-axis) against the forecasted sales (x-axis). The correlation between the change in the forecasted sales and the change in the actual sales is found above each panel.

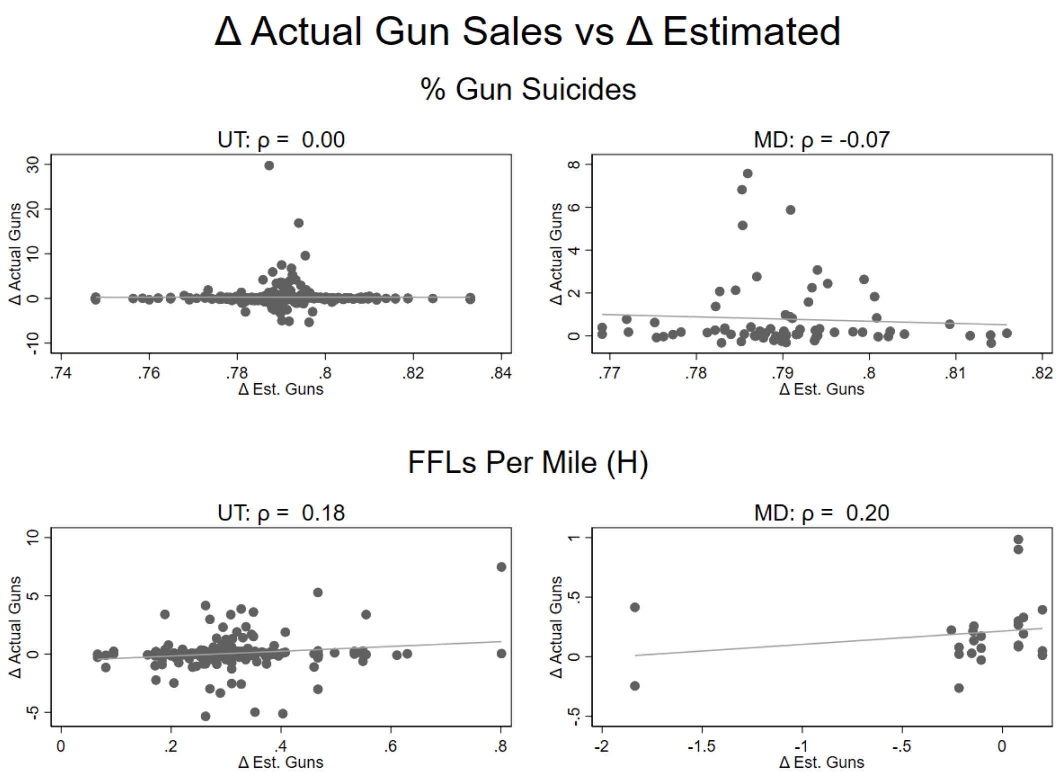
We find a relatively weak correlation between the change in gun sales and the change in forecasted gun sales using both proxies - which is expected considering we are using pooled OLS to generate a coefficient estimate and applying this coefficient to completely different states. However, we note that there is no positive correlation between the change in gun sales and the change in forecasted gun sales when using the coefficient generated using %GS. When generating the coefficient using FFLs PM (H), we observe a modest but positive correlation between the actual change in gun sales and the forecasted change in both states.

Yearly, county-level gun sales data is rare. Therefore a natural worry is that there is some unobserved variable that is coincidentally causing the forecasts to favor FFLs PM (H). To address this possibility, we replicate the previous results but this time with concealed carry permit data.[35] We forecast newly issued concealed carry permits in Minnesota, New York, Tennessee, and Louisiana again using data from Pennsylvania and Massachusetts to generate the coefficients ($\beta_0 = .226[p < 0.001]$ and $\beta_1 = .038[p = 0.810]$ using %GS and $\beta_0 = 0.145[p = 0.001]$ and $\beta_1 = .971[p < 0.001]$ using FFLs PM (H)). The resulting forecasts are found in Figure A4. Here again, we find the % GS-based forecasts have no relationship with the actual change in concealed carry permits while the FFL-based forecasts do relatively better.

[34] **We invite other researchers to replicate our analysis with the additional California data.**

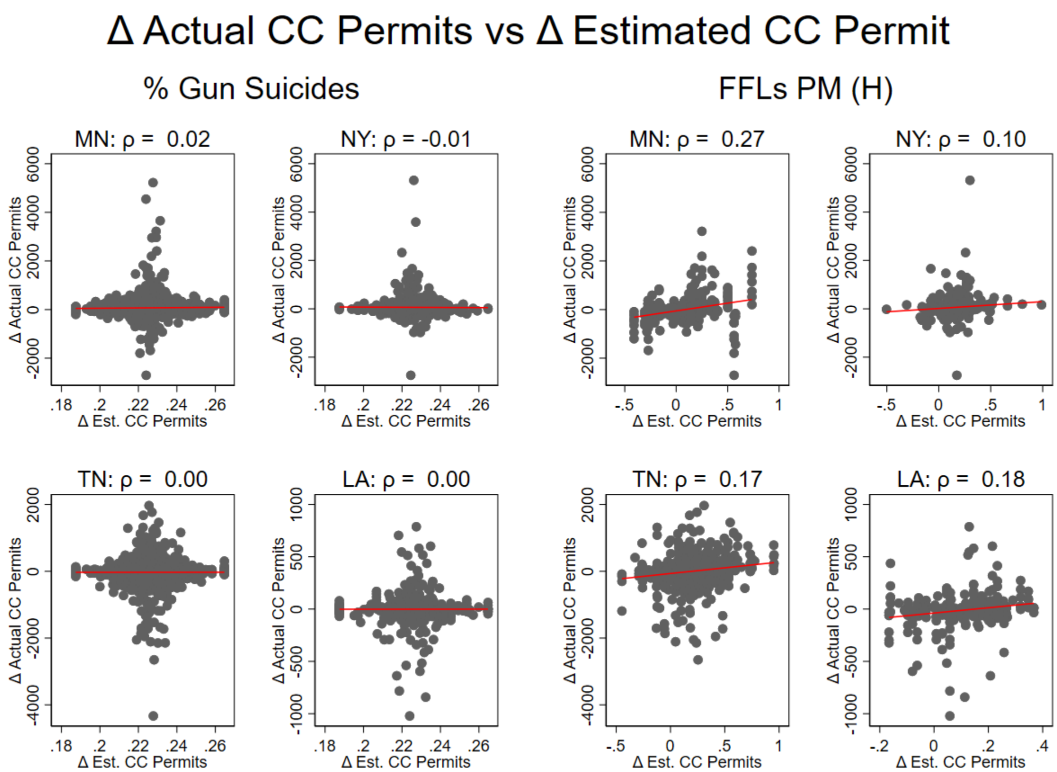
[35] The concealed carry permit data comes from a contemporaneous project that involves building a concealed carry permit database.

Figure A3: A "Dirty" Forecast of Gun Sales



Notes: Correlations between the change in gun sales and the estimated change in gun sales. Top panels use %GS to estimate the change in gun sales and these coefficients are used to forecast the change in gun sales in Maryland and Utah. Bottom use FFLs PM (H).

Figure A4: A "Dirty" Forecast of Concealed Carry Permits



Notes: Correlations between the change in concealed carry permits and the estimated change in concealed carry permits. Left panels use %GS to estimate the change in concealed carry permits and these coefficients are used to estimate the change in guns in Minnesota, New York, Tennessee, and Louisiana. Right use FFLs PM (H).

B Point Estimates of the Relationship between the Direct Measure of Firearms and Indirect Measures

Table B1: Handgun Sales and Gun Measures

	Pennsylvania						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Handguns	-0.00149	-0.0282	0.0531	0.516*	-0.00266	0.0451***	1.731***
	(-0.45)	(-1.79)	(1.58)	(2.39)	(-0.72)	(4.18)	(3.61)
Obs	938	804	804	804	804	804	804
Groups	67	67	67	67	67	67	67
Adj. R^2	0.145	0.955	0.980	0.981	0.990	0.989	0.988

	Massachusetts						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Handguns	0.00400	0.0132	0.132	0.433	0.00714**	0.0366*	1.862**
	(0.62)	(1.01)	(1.66)	(0.72)	(3.63)	(2.22)	(4.19)
Obs	196	168	168	168	168	168	168
Groups	14	14	14	14	14	14	14
Adj. R^2	0.0560	0.973	0.967	0.987	0.997	0.987	0.997

	Massachusetts & Pennsylvania						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Handguns	-0.00148	-0.0183	0.0780*	0.643**	-0.000230	0.0526***	2.057***
	(-0.51)	(-1.28)	(2.35)	(3.18)	(-0.07)	(5.61)	(5.45)
Obs	1134	972	972	972	972	972	972
Groups	81	81	81	81	81	81	81
Adj. R^2	0.380	0.963	0.972	0.979	0.991	0.986	0.988

Notes: Fixed effects regression results. The top panel is the Pennsylvania sample, the middle panel is the Massachusetts sample, and the bottom panel is the pooled sample. Each model contains county and year fixed effects. The column label indicates the measure of guns used. Standard errors are clustered at the county. t-statistics in parentheses; * $p<0.05$, ** $p<0.01$, *** $p<0.001$. All models control for population, the unemployment rate, the percentage of the county that identifies as Black/male, the population density, and the business density. Estimates without the control variables are found in the Appendix (Table B4).

Table B2: Long-gun Sales and Gun Measures

	Pennsylvania						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC(H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Long-guns	-0.000658	-0.00940	0.0176	0.156	-0.00214	0.0109	0.277
	(-0.25)	(-1.22)	(1.09)	(1.40)	(-1.35)	(1.41)	(1.00)
Obs	938	804	804	804	804	804	804
Groups	67	67	67	67	67	67	67
Adj. R^2	0.145	0.954	0.979	0.980	0.990	0.988	0.987

	Massachusetts						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Long-guns	0.00571	0.0161	0.137	0.0821	0.00868^{**}	0.0302	2.167^{***}
	(0.69)	(0.77)	(1.15)	(0.11)	(4.18)	(1.89)	(4.49)
Obs	196	168	168	168	168	168	168
Groups	14	14	14	14	14	14	14
Adj. R^2	0.0558	0.973	0.965	0.987	0.997	0.987	0.997

	Massachusetts & Pennsylvania						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Long-guns	-0.000822	-0.00639	0.0290	0.236	-0.00125	0.0142	0.461
	(-0.32)	(-0.90)	(1.50)	(1.86)	(-0.88)	(1.76)	(1.49)
Obs	1134	972	972	972	972	972	972
Groups	81	81	81	81	81	81	81
Adj. R^2	0.381	0.963	0.971	0.977	0.991	0.984	0.987

Notes: Fixed effects regression results. The top panel is the Pennsylvania sample, the middle panel is the Massachusetts sample, and the bottom panel is the pooled sample. Each model contains county and year fixed effects. The column label indicates the measure of guns used. Standard errors are clustered at the county. t-statistics in parentheses; * $p<0.05$, ** $p<0.01$, *** $p<0.001$. All models control for population, the unemployment rate, the percentage of the county that identifies as Black/male, the population density, and the business density. Estimates without the control variables are found in the Appendix (Table B5).

Table B3: Concealed Carry, Gun Sales, and Gun Measures

Pennsylvania									
	Model 1 Handguns 1000s	Model 2 Long-guns 1000s	Model 3 % Gun Suicides	Model 4 FFLs PC	Model 5 FFLs PM	Model 6 FFLs Count	Model 7 FFLs PC (H)	Model 8 FFLs PM (H)	Model 9 FFLs Count (H)
CC Permits	1.201***	0.288***	-0.00140	-0.0400	0.0888*	0.692*	-0.0109	0.0668***	2.548**
	(5.63)	(3.63)	(-0.28)	(-1.57)	(2.31)	(2.36)	(-1.90)	(3.97)	(3.37)
Obs	938	938	938	804	804	804	804	804	804
Groups	67	67	67	67	67	67	67	67	67
Adj. R^2	0.949	0.808	0.145	0.954	0.980	0.980	0.990	0.989	0.988

Massachusetts									
	Model 1 Handguns 1000s	Model 2 Long-guns 1000s	Model 3 % Gun Suicides	Model 4 FFLs PC	Model 5 FFLs PM	Model 6 FFLs Count	Model 7 FFLs PC (H)	Model 8 FFLs PM (H)	Model 9 FFLs Count (H)
CC Permits	0.226***	0.221***	0.0110	-0.000710	0.0619	0.360	0.000537	0.0155	1.196**
	(5.51)	(4.96)	(1.12)	(-0.18)	(1.52)	(1.19)	(0.40)	(0.94)	(3.43)
Obs	196	196	196	168	168	168	168	168	168
Groups	14	14	14	14	14	14	14	14	14
Adj. R^2	0.927	0.900	0.0624	0.972	0.964	0.987	0.996	0.987	0.997

Pennsylvania & Massachusetts									
	Model 1 Handguns 1000s	Model 2 Long-guns 1000s	Model 3 % Gun Suicides	Model 4 FFLs PC	Model 5 FFLs PM	Model 6 FFLs Count	Model 7 FFLs PC (H)	Model 8 FFLs PM (H)	Model 9 FFLs Count (H)
CC Permits	0.776***	0.209***	0.00110	-0.0296	0.115**	0.764**	-0.00698	0.0784***	2.661***
	(3.91)	(4.18)	(0.29)	(-1.90)	(2.80)	(2.93)	(-1.87)	(5.23)	(4.61)
Obs	1134	1134	1134	972	972	972	972	972	972
Groups	81	81	81	81	81	81	81	81	81
Adj. R^2	0.930	0.817	0.381	0.963	0.972	0.978	0.991	0.986	0.988

Notes: Fixed effects regression results. The top panel is the Pennsylvania sample, the middle panel is the Massachusetts sample, and the bottom panel is the pooled sample. Each model contains county and year fixed effects. The column label indicates the measure of guns used. Standard errors are clustered at the county. t-statistics in parentheses; * $p<0.05$, ** $p<0.01$, *** $p<0.001$. *** $p<0.001$. All models control for population, the unemployment rate, the percentage of the county that identifies as Black/male, the population density, and the business density. Estimates without the control variables are found in the Appendix (Table B6).

B.1 Replication of Results without Control Variables

Table B4: Handgun Sales and Gun Measures

	Pennsylvania						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Handguns	-0.00120	-0.0231	0.0974*	0.723**	-0.00477	0.0591***	2.163***
	(-0.35)	(-1.44)	(2.64)	(3.17)	(-1.24)	(6.39)	(5.32)
Obs	938	804	804	804	804	804	804
Groups	67	67	67	67	67	67	67
Adj. R^2	0.147	0.951	0.977	0.979	0.989	0.988	0.987

	Massachusetts						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Handguns	-0.00201	0.00178	0.0662	-0.0348	0.00120	0.0153	0.753*
	(-0.32)	(0.27)	(1.00)	(-0.17)	(0.72)	(2.02)	(2.98)
Obs	196	168	168	168	168	168	168
Groups	14	14	14	14	14	14	14
Adj. R^2	0.0579	0.973	0.886	0.987	0.996	0.986	0.997

	Massachusetts & Pennsylvania						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Handguns	-0.00148	-0.0211	0.0775*	0.483*	-0.00556	0.0432***	1.585**
	(-0.51)	(-1.58)	(2.23)	(2.33)	(-1.47)	(3.69)	(3.12)
Obs	1134	972	972	972	972	972	972
Groups	81	81	81	81	81	81	81
Adj. R^2	0.380	0.961	0.967	0.977	0.991	0.985	0.987

Notes: Fixed effects regression results. The top panel is the Pennsylvania sample, the middle panel is the Massachusetts sample, and the bottom panel is the pooled sample. Each model contains county and year fixed effects. The column label indicates the measure of guns used. Standard errors are clustered at the county. t-statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001.

Table B5: Long-gun Sales and Gun Measures

	Pennsylvania						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Long-guns	-0.000975	-0.00995	0.0381	0.287*	-0.00299	0.0182	0.537
	(-0.39)	(-1.19)	(1.80)	(2.08)	(-1.62)	(1.98)	(1.65)
Obs	938	804	804	804	804	804	804
Groups	67	67	67	67	67	67	67
Adj. R^2	0.147	0.951	0.976	0.976	0.989	0.986	0.986

	Massachusetts						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Long-guns	-0.00186	0.00411	0.136	-0.192	0.00352	0.0262	1.399*
	(-0.18)	(0.31)	(0.93)	(-0.45)	(1.30)	(1.51)	(2.91)
Obs	196	168	168	168	168	168	168
Groups	14	14	14	14	14	14	14
Adj. R^2	0.0574	0.973	0.887	0.987	0.996	0.986	0.997

	Massachusetts & Pennsylvania						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Long-guns	-0.00122	-0.0109	0.0354	0.219	-0.00366	0.0148	0.448
	(-0.50)	(-1.27)	(1.74)	(1.81)	(-1.54)	(1.98)	(1.62)
Obs	1134	972	972	972	972	972	972
Groups	81	81	81	81	81	81	81
Adj. R^2	0.380	0.961	0.966	0.976	0.991	0.984	0.986

Notes: Fixed effects regression results. The top panel is the Pennsylvania sample, the middle panel is the Massachusetts sample, and the bottom panel is the pooled sample. Each model contains county and year fixed effects. The column label indicates the measure of guns used. Standard errors are clustered at the county. t-statistics in parentheses; * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Table B6: Concealed Carry, Gun Sales, and Gun Measures

	Pennsylvania								
	Model 1 Handguns 1000s	Model 2 Long-guns 1000s	Model 3 % Gun Suicides	Model 4 FFLs PC	Model 5 FFLs PM	Model 6 FFLs Count	Model 7 FFLs PC (H)	Model 8 FFLs PM (H)	Model 9 FFLs Count (H)
CC Permits	1.261***	0.331*	-0.000279	-0.0408	0.167*	1.041*	-0.0148*	0.0958***	3.421***
	(5.26)	(2.54)	(-0.05)	(-1.59)	(2.61)	(2.64)	(-2.27)	(4.68)	(4.36)
Obs	938	938	938	804	804	804	804	804	804
Groups	14	14	67	67	67	67	67	67	67
Adj. R^2	0.945	0.804	0.147	0.951	0.977	0.978	0.989	0.988	0.987

	Massachusetts								
	Model 1 Handguns 1000s	Model 2 Long-guns 1000s	Model 3 % Gun Suicides	Model 4 FFLs PC	Model 5 FFLs PM	Model 6 FFLs Count	Model 7 FFLs PC (H)	Model 8 FFLs PM (H)	Model 9 FFLs Count (H)
CC Permits	0.703***	0.431***	0.00541	-0.000981	0.0377	0.212	0.000520	0.0207	1.302**
	(4.87)	(10.26)	(0.53)	(-0.17)	(0.98)	(0.72)	(0.29)	(1.18)	(3.77)
Obs	196	196	196	168	168	168	168	168	168
Groups	14	14	14	14	14	14	14	14	14
Adj. R^2	0.855	0.851	0.0594	0.973	0.883	0.987	0.996	0.986	0.997

	Pennsylvania & Massachusetts								
	Model 1 Handguns 1000s	Model 2 Long-guns 1000s	Model 3 % Gun Suicides	Model 4 FFLs PC	Model 5 FFLs PM	Model 6 FFLs Count	Model 7 FFLs PC (H)	Model 8 FFLs PM (H)	Model 9 FFLs Count (H)
CC Permits	0.905***	0.290***	0.00107	-0.0299	0.130**	0.766**	-0.0115*	0.0785***	2.588***
	(5.33)	(4.74)	(0.28)	(-1.83)	(2.87)	(2.79)	(-2.35)	(4.95)	(4.04)
Obs	1134	1134	1134	972	972	972	972	972	972
Groups	81	81	81	81	81	81	81	81	81
Adj. R^2	0.920	0.812	0.380	0.961	0.967	0.977	0.991	0.986	0.987

Notes: Fixed effects regression results. The top panel is the Pennsylvania sample, the middle panel is the Massachusetts sample, and the bottom panel is the pooled sample. Each model contains county and year fixed effects. The column label indicates the measure of guns used. Standard errors are clustered at the county. t-statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001. *** p<0.001.

B.2 Differences in Gun Sales by Dealer Type

Table B7: Average Handgun Sales by County Type and Year

	Low FFLs PM	High FFLs PM	P-value	HIGH FFLs PC	LOW FFLs PC	P-value
2006	.56	4.732	0	.596	3.437	.001
2007	.611	4.812	0	.671	3.735	0
2008	.78	5.37	0	.854	4.899	0
2009	1.142	6.651	0	1.004	5.216	0
2010	.936	6.575	0	1.067	5.409	0
2011	1.204	8.458	0	1.239	6.945	0
2012	1.755	12.247	0	1.773	9.229	0
2013	1.994	11.917	0	1.934	9.74	0
2014	1.545	10.899	0	1.661	8.884	0
2015	1.966	12.495	0	1.793	10.424	0
2016	2.344	14.455	0	1.829	11.617	0
2017	1.892	13.485	0	1.794	10.996	0
2018	1.774	11.898	0	1.706	9.766	0
2019	1.829	11.995	0	1.596	9.808	0

Notes: Types are based on the number of FFLs Per mile (first three columns) and number of FFLs per capita (right three columns). Low indicates the county is in the bottom quartile of the type and high indicates the county is in the top quartile. Data includes observations from Pennsylvania and Massachusetts.

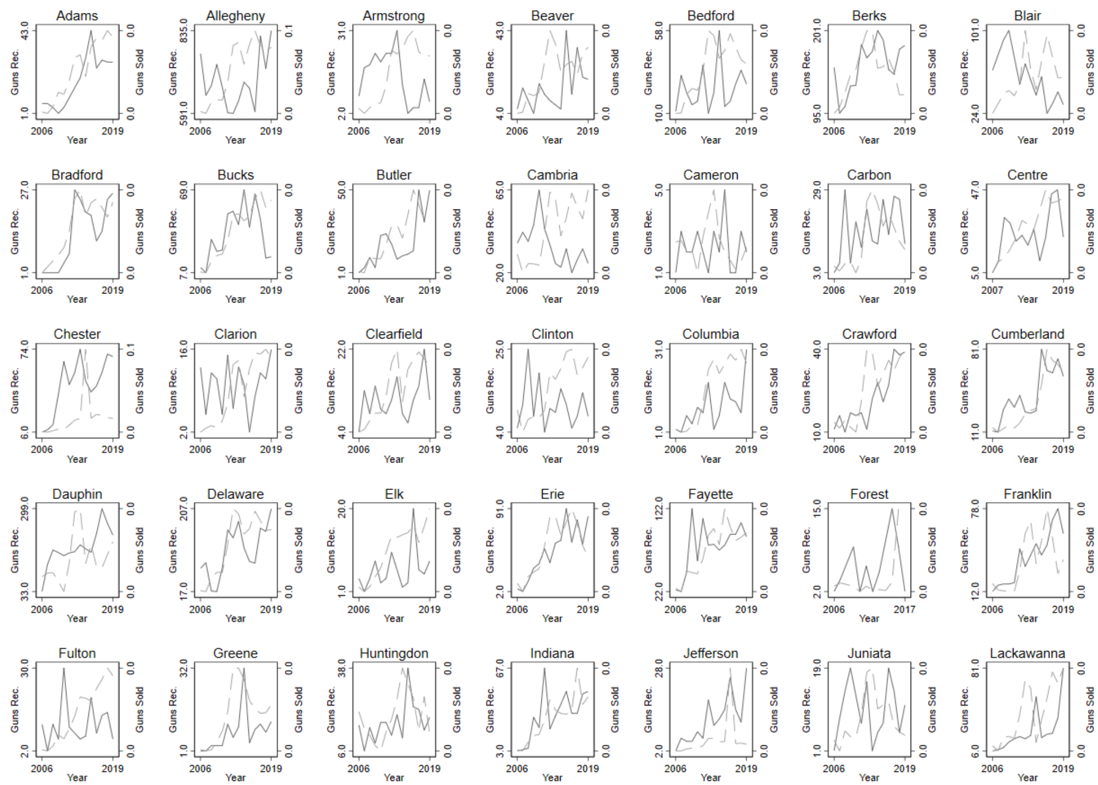
Table B8: Average Long-gun Sales by County Type and Year

	Low FFLs PM	High FFLs PM	P-value	HIGH FFLs PC	LOW FFLs PC	P-value
2006	1.491	5.518	0	1.44	3.16	.056
2007	1.349	5.049	.001	1.402	3.298	.023
2008	1.451	5.054	0	1.63	4.47	.015
2009	1.863	6.269	.001	1.644	4.299	.004
2010	1.558	5.965	.001	1.719	4.195	.007
2011	1.822	6.98	0	1.959	4.791	.007
2012	2.305	9.858	0	2.475	6.531	.004
2013	2.302	9.696	0	2.493	7.011	.002
2014	2.001	10.388	.001	2.172	8.089	.021
2015	2.258	8.044	0	2.215	6.1	.002
2016	2.301	9.413	0	3.52	6.924	.089
2017	2.122	8.373	0	2.08	6.081	.002
2018	2.124	7.417	0	2.182	5.613	.005
2019	2.304	7.062	0	2.037	5.301	.005

Notes: Types are based on the number of FFLs Per mile (first three columns) and number of FFLs per capita (right three columns). Low indicates the county is in the bottom quartile of the type and high indicates the county is in the top quartile. Data includes observations from Pennsylvania and Massachusetts.

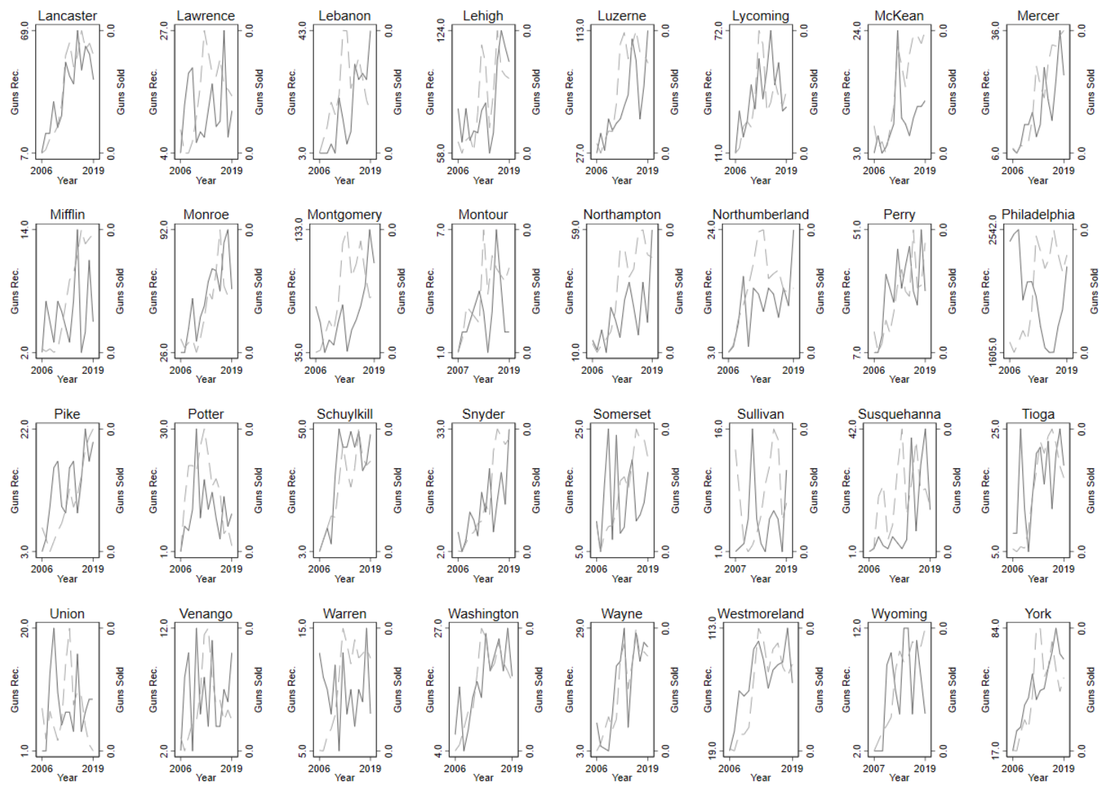
B.3 Gun Traces

Figure B1: Successful Gun Traces and Recoveries by Year



Notes: Number of recovered crime guns that were traced to a Pennsylvania dealer by year (solid line) and guns (handgun and long-gun) sold (dashed line).

Figure B2: Successful Gun Traces and Recoveries by Year



Notes: Number of recovered crime guns that were traced to a Pennsylvania dealer by year (solid line) and guns (handgun and long-gun) sold (dashed line).

B.4 Gun Homicide and Gun Prevalence

Table B9: Estimated Relationship between Gun Homicide and Measures of Gun Prevalence

	Gun Prevalence Measures								
	%GS	LTC	HG	FFLs	FFLs PC	FFLs PM	FFLs (H)	FFLs PC (H)	FFLs PM(H)
Gun Measure	-0.170	0.00938	0.00224	-0.000662	-0.151	0.00785	0.00121	-0.00559	0.0686
	(-0.78)	(0.59)	(0.29)	(-0.39)	(-1.91)	(0.65)	(1.08)	(-0.04)	(1.64)
% Black	-0.0387	0.0226	-0.0389	-0.00543	-0.0103	-0.00597	-0.00424	-0.00687	-0.00262
	(-0.85)	(0.62)	(-0.80)	(-0.17)	(-0.30)	(-0.18)	(-0.14)	(-0.21)	(-0.10)
% Male	0.226*	0.0534	0.186	0.172	0.157	0.178	0.152	0.168	0.147
	(2.25)	(0.22)	(0.81)	(1.59)	(1.40)	(1.73)	(1.39)	(1.55)	(1.38)
Pop. (10,000s)	-0.00910	0.0162*	-0.00775	-0.00781	-0.00876	-0.00419	-0.00753	-0.00757	-0.00759
	(-0.82)	(2.15)	(-0.68)	(-0.82)	(-0.89)	(-0.45)	(-0.90)	(-0.78)	(-1.01)
Poverty	-0.0158	-0.00809	-0.0142	-0.0148	-0.0176	-0.0102	-0.0000577	-0.0139	0.00716
	(-1.02)	(-0.76)	(-0.81)	(-0.97)	(-1.31)	(-0.59)	(-0.00)	(-0.88)	(0.39)
Constant	-4.774	-0.800	-3.118	-3.202	-2.132	-4.055	-2.925	-3.062	-3.008
	(-1.13)	(-0.07)	(-0.31)	(-0.70)	(-0.44)	(-0.90)	(-0.65)	(-0.68)	(-0.68)
Obs	869	715	869	948	948	948	948	948	948
Groups	79	65	79	79	79	79	79	79	79
Pseudo R^2	0.895	0.910	0.895	0.895	0.895	0.895	0.895	0.895	0.895

	Natural Log of Gun Prevalence Measures								
	%GS	LTC	HG	FFLs	FFLs PC	FFLs PM	FFLs (H)	FFLs PC (H)	FFLs PM(H)
Gun Measure	-0.0174	0.212**	-0.0419	-0.000662	0.0659	0.0721	0.523*	0.505*	0.523*
	(-0.29)	(2.90)	(-1.20)	(-0.39)	(0.61)	(0.67)	(2.15)	(2.09)	(2.15)
% Black	-0.0362	-0.0864	-0.0164	-0.00543	-0.00385	-0.00430	-0.00281	0.00472	-0.00281
	(-0.78)	(-1.72)	(-0.30)	(-0.17)	(-0.11)	(-0.13)	(-0.11)	(0.18)	(-0.11)
% Male	0.227*	0.0601	0.277*	0.172	0.175	0.175	0.161	0.154	0.161
	(2.28)	(0.48)	(2.53)	(1.59)	(1.65)	(1.66)	(1.56)	(1.48)	(1.56)
Pop. (10,000s)	-0.00820	-0.0131	-0.00228	-0.00781	-0.00393	-0.00428	-0.00965	-0.00629	-0.00965
	(-0.71)	(-1.34)	(-0.19)	(-0.82)	(-0.38)	(-0.44)	(-1.32)	(-0.89)	(-1.32)
Poverty	-0.0157	-0.00165	-0.0190	-0.0148	-0.0113	-0.0110	0.0109	0.0103	0.0109
	(-1.02)	(-0.12)	(-1.38)	(-0.97)	(-0.72)	(-0.70)	(0.65)	(0.61)	(0.65)
Constant	-5.083	4.140	-8.417	-3.202	-3.790	-4.026	-5.929	-3.138	-4.040
	(-1.21)	(0.73)	(-1.56)	(-0.70)	(-0.85)	(-0.89)	(-1.42)	(-0.72)	(-0.95)
Obs	824	869	858	948	936	936	948	948	948
Groups	78	79	78	79	78	78	79	79	79
Pseudo R^2	0.894	0.896	0.895	0.895	0.895	0.895	0.895	0.895	0.895

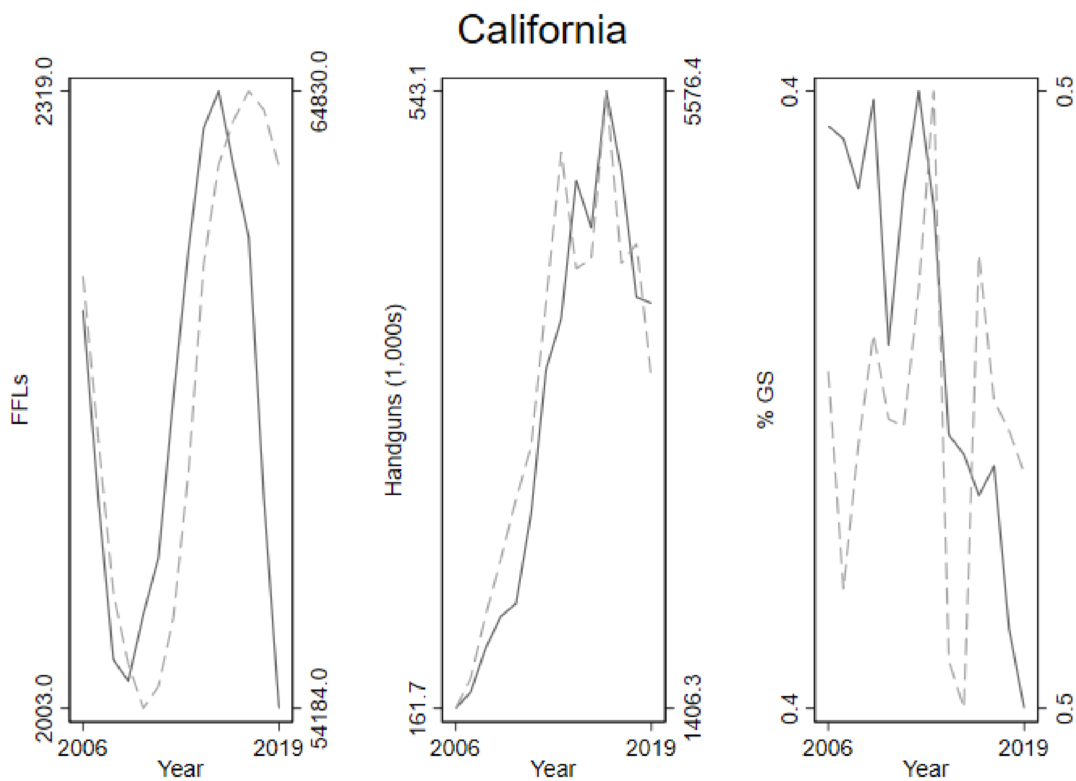
Notes: Estimated relationship between gun prevalence measures and gun homicides. Measure indicated by column label. Top panel uses the raw measure; the bottom uses the natural log of the measure. All models are fixed effects Poisson and the gun prevalence measures are lagged three years. Standard errors are clustered at the county. t-statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001. Coefficients of the gun prevalence measures are found in Figure 12.

C Replication with California Data

Table C1: Summary Statistics

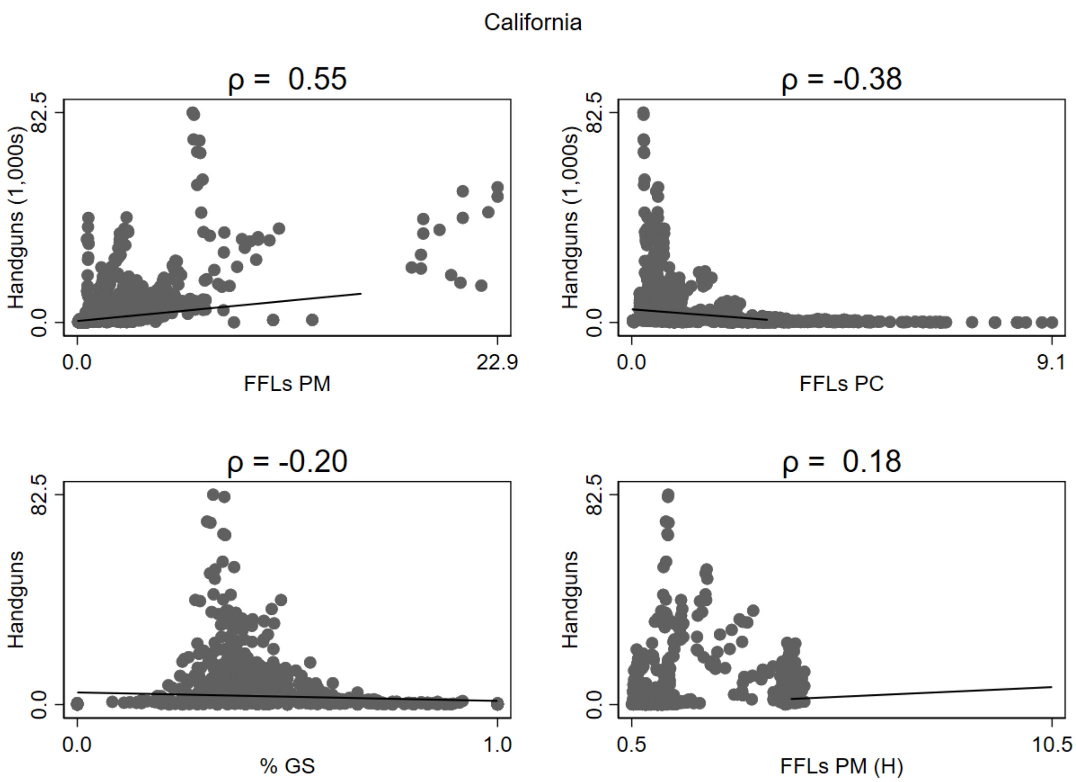
	California			
	Mean	Std. Dev.	Min	Max
Handguns (1,000s)	6.05	10.8	0.0010	82.5
Long-guns (1,000s)	.	.	.	.
CC Permits (1,000s)	.	.	.	.
% GS	0.46	0.21	0	1
FFLs (H)	273.2	257.6	81	1222
FFLs PM (H)	1.64	1.28	0.46	4.59
FFLs (Count)	37.5	48.9	0	382
FFLs PM (100s)	2.30	3.17	0	22.9
FFLs PC (10,000s)	1.77	1.61	0	9.07
Pop. (10,000s)	65.6	143.0	0.11	1017.0
Pop. Density	682.2	2376.2	1.45	18868.4
U. Rate	8.82	4.27	2.04	28.9
% Male	50.6	2.27	48.0	64.9
% Black	4.22	3.51	0.083	17.2
Bus. PM (H)	661.7	999.5	41.8	3134.2
Bus. (H)	88525.6	107647.2	7196	456694
Year	2012.5	4.03	2006	2019
Observations	812			

Figure C1: Trends in Gun Measures (2006-2019)



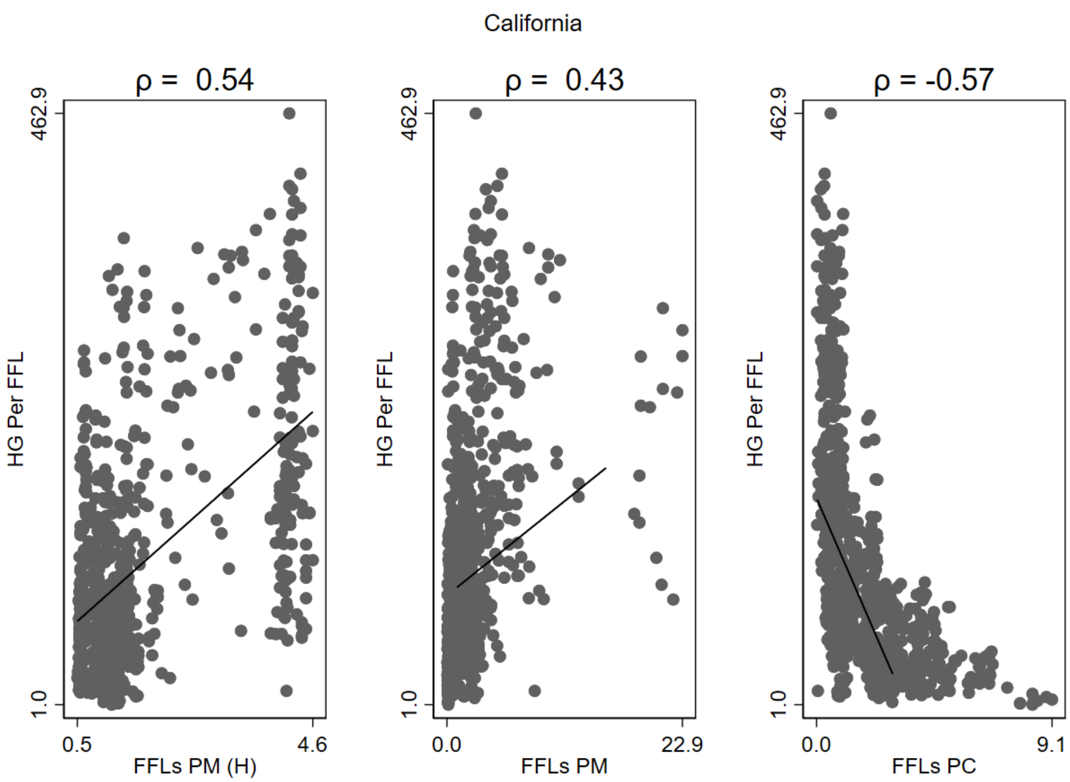
Notes: From top left to bottom right for the left-hand panels: FFLs (dealer and pawn license holders), reported handguns sold, and % of suicides involving a gun. The dashed line corresponds to national trends. The solid line is the specific state only.

Figure C2: Simple Correlations of Gun Proxies and Reported Gun Sales



Notes: Correlations between gun sales and various measures of gun prevalence. The line corresponds to the OLS regression line.

Figure C3: Guns Sold per FFL vs FFLs Per Mile and FFLS Per Person



Notes: Correlations between gun sales per FFL and gun dealers per mile and gun dealers per 10,000 people. The line corresponds to the OLS regression line. From left to bottom right: gun dealers per 100 (county *i* and counties adjacent to *i*) miles vs. handguns sold per FFL, gun dealers per 100 miles vs. handguns sold per FFL, and gun dealers per 10,000 people vs. handguns sold per FFL.

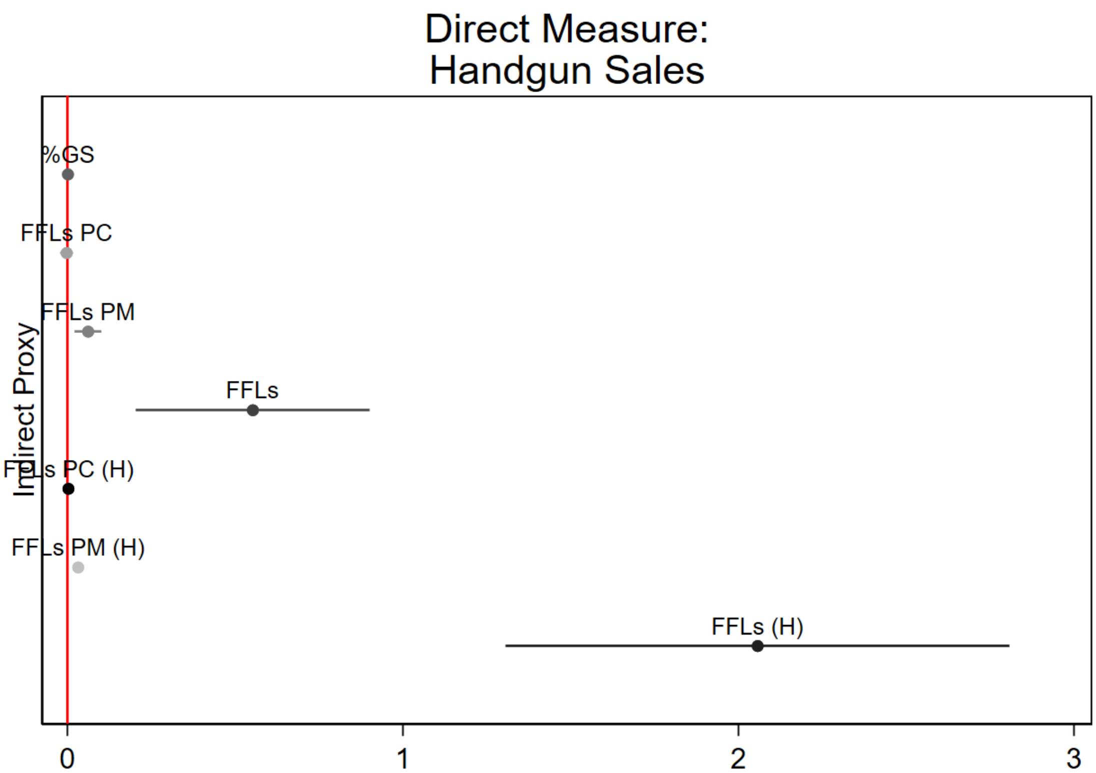
Table C2: Handgun Sales and Gun Measures

	California						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Handguns	0.00140	0.00800	0.0426	0.603	0.00417*	0.0100*	1.761
	(0.69)	(1.10)	(1.26)	(1.96)	(2.29)	(2.01)	(1.13)
Obs	801	689	689	689	689	689	689
Groups	58	58	58	58	58	58	58
Adj. R^2	0.266	0.878	0.979	0.984	0.992	0.996	0.993

	California						
	Model 1 % Gun Suicides	Model 2 FFLs PC	Model 3 FFLs PM	Model 4 FFLs Count	Model 5 FFLs PC (H)	Model 6 FFLs PM (H)	Model 7 FFLs Count (H)
Handguns	0.000682	0.00227	0.0301	0.373	0.00440*	0.00728*	2.669*
	(0.52)	(0.41)	(1.45)	(0.89)	(2.64)	(2.29)	(2.34)
Obs	801	689	689	689	689	689	689
Groups	58	58	58	58	58	58	58
Adj. R^2	0.266	0.873	0.968	0.984	0.992	0.996	0.993

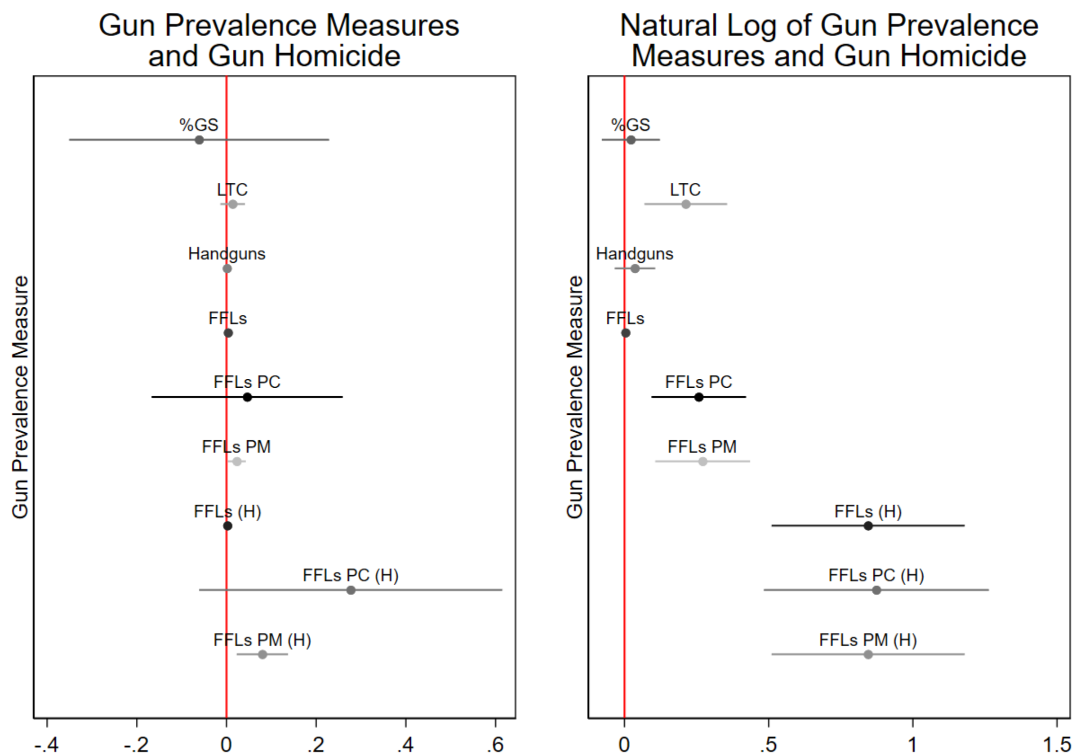
Notes: Fixed effects regression results. The top panel includes control variables and the bottom panel does not. Each model contains county and year fixed effects. The column label indicates the measure of guns used. Standard errors are clustered at the county. t-statistics in parentheses; * p<0.05, ** p<0.01, *** p<0.001. The top panel models control for population, the unemployment rate, the percentage of the county that identifies as Black/male, the population density, and the business density.

Figure C4: Estimated relationship between Indirect Measures of Gun Prevalence and Direct Measures



Notes: Fixed effects regression results. Each model contains county and year-fixed effects. The sub-figure title indicates the direct measure of guns used. Standard errors are clustered at the county. All models control for population, the unemployment rate, the percentage of the county that identifies as Black/male, the population density, and the business density. Models use data from Massachusetts, Pennsylvania, and California.

Figure C5: Gun Prevalence Measures and Homicide



Notes: Estimated relationship between gun prevalence measures and gun homicide. All models are fixed effects Poisson with county clustered standard errors. Other explanatory variables include population, % Black, % male, and poverty rate. Data is from Pennsylvania, Massachusetts, and California and is from 2006-2019.