Article

Firearm Availability, Homicide, and the Context of Structural Disadvantage

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Abstract

This study examines how legal and illegal firearm availability correspond to subsequent rates of firearm and non-firearm homicide in 226 U.S. cities from 2010 through 2017. We also assess how city-level economic disadvantage conditions this relationship. Results show that greater availability of illegal guns corresponds to future rates of firearm homicide while the rate of legal firearms dealers does not significantly influence firearm homicide. The association between firearm availability and homicide is conditional upon level of structural economic disadvantage. Our findings support efforts to decrease access to illegal firearms to reduce gun violence, especially among vulnerable and disadvantaged communities.

Keywords

gun violence, homicide, gun markets, structural disadvantage

Every year, assaultive gun violence claims the lives of tens of thousands of people in the United States (U.S.) (Centers for Disease Control and Prevention [CDC], 2020a; Thompson, 2021). Although Americans are not uniquely aggressive (Zimring & Hawkins, 1999), violence is far more likely to end in death in the U.S. than in other peer industrialized nations around the world (Miller et al., 2013). The availability of firearms has been cited as a major reason for America's uniquely lethal brand of violence, contributing to a firearm homicide rate approximately 24 times higher than comparable high-income nations (Grinshteyn & Hemenway, 2016). Despite

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exceptionally high rates of gun ownership and firearm homicide in the U.S., however, it remains uncertain how different types of firearm availability influence rates of gun violence across cities. In particular, it is unclear how the availability of guns from federally licensed firearm dealers (FFLs) compared to illicit channels impacts homicide risk. Furthermore, knowledge is limited regarding how the dynamics of firearm availability and homicide operate in different types of cities, especially those suffering from greater structural economic disadvantage.

Prior research has explored the effects of gun availability on violent crime, yet the literature remains limited in three notable ways. First, most studies that examine the influence of gun availability on violent crime leverage broad measures of availability or examine legal and illegal availability separately. Although researchers have found that greater legal availability of firearms through FFLs heightens risk for gun violence in major cities (Semenza, Stansfield, & Link, 2020; Steidley, Ramey, & Shrider, 2017; Wiebe et al., 2009), others have shown that the availability of illegal firearms increases the risk of gun violence in the community (Dierenfeldt et al., 2017; Stansfield, Semenza, & Steidley, 2021; Stolzenberg & D'Alessio, 2000; Yu et al., 2020). Only one study to our knowledge has assessed the concurrent influence of *both* illegal and legal gun availability on firearm homicide rates, specifically across counties in South Carolina (Stolzenberg & D'Alessio, 2000). Second, significant data limitations have made it difficult to generate reliable and validated measures of gun availability (Kleck, 2015). Studies have used broad proxies of gun availability, yet in almost all cases researchers have not made a distinction between legal and illegal types of access. Finally, research on community firearm availability has been limited in geographic scope. Although select studies have drawn on national samples to examine the influence of availability on violence (Dierenfeldt et al., 2017; Steidley et al., 2017; Wiebe et al., 2009), most have relied on samples from a single state (Stolzenberg & D'Alessio, 2000) or city (Cook et al., 2015; Hureau & Braga, 2018; McDowall, 1991; Yu et al., 2020). While these studies provide crucial information on the workings of gun markets in those areas, it remains difficult to draw broader conclusions about the influence of various types of gun availability on homicide rates.

Taken together, notable issues of measurement and generalizability have hampered a comprehensive understanding of how gun availability impacts violent crime and homicide in the U.S. To address these limitations, we leverage a unique dataset of American cities from 2010 to 2017 to examine how both legal and illegal firearm availability influence rates of homicide over time. We also assess how the economic context of cities moderates the dynamics of gun availability and firearm violence. Based on the results, we discuss implications for gun violence prevention strategies, as well as opportunities for future research on the causes and consequences of gun violence in American communities.

Why Should Firearm Availability Influence Violent Crime?

Two prevailing perspectives explain why firearm availability should influence patterns of violent crime. The first posits that greater firearm availability will increase

gun violence. In his objective dangerousness hypothesis, Zimring (1968) proposed that greater gun availability is likely to impact (a) the frequency with which guns are used in the course of a crime and (b) the likelihood that a crime will result in a homicide given the heightened lethality of firearms. This perspective suggests that the instrumentality of firearms makes taking another person's life easier and more efficient, rendering it more likely that a person will die as a result of a violent altercation (Cook, 1983; Hepburn & Hemenway, 2004). Cook (1983) argues that guns are particularly valuable to those that would otherwise be unable to carry out an attack, especially against victims that could defend themselves against weapons such as knives or blunt objects. The argument for an objective dangerousness hypothesis suggests that greater public gun availability will increase the likelihood that guns will be used in the commission of crime, thereby heightening homicide even if overall aggression remains the same.

Opposing researchers assert that greater firearm availability should *deter* violent offenses and decrease rates of violent crime, since those carrying guns for self-defense may ward off potential attackers and stop a violent crime from ever occurring. Within this framework, guns confer power both to potential aggressors and victims looking to resist aggression (Altheimer, 2008; Kleck, 1997), arming more citizens and generating a net decrease in violent crime. However, defensive gun use has been shown to be quite rare and largely ineffective for reducing the risk of injury (Hemenway & Solnick, 2015). These competing viewpoints (objective dangerousness vs. defensive use) have shaped the debate over whether gun availability matters for violent crime, simultaneously influencing the national conversation around gun control and supply-side efforts to reduce gun violence in the U.S.

Empirical evidence on this issue offers mixed conclusions due, in part, to the ways that researchers have measured gun availability. For instance, public health scholarship on firearm availability in the home robustly demonstrates that firearm ownership increases the risk for homicide (Anglemyer et al., 2014; Kellerman et al., 1993), suicide (Swanson et al., 2020), and non-fatal firearm injuries (Kellermann et al., 1998). Results from community-level ecological studies, however, remain less conclusive. Many of these studies have employed broad measures of gun availability such as the ratio of firearm suicides to all suicides (FS/S) (Siegel et al., 2013), the proportion of firearm-related homicides (Shenassa et al., 2006), or the number of gun owner licenses and registrations (see Azrael et al., 2004; Kleck, 2015 for overviews of measurements in prior research). Although numerous city- and state-level studies have found a positive relationship between gun availability and violent crime (Altheimer, 2008; Dierenfeldt et al., 2017; McDowall, 1991; Semenza et al., 2020; Steidley et al., 2017; Yu et al., 2020), select studies have also uncovered a negative association (Bordua, 1986; Kleck & Patterson, 1993).

We contest that the lack of clarity in the empirical literature is at least partially due to the fact that measures of gun availability are not typically classified by legality. As Cook (1979) notes, different types of access to firearms may have divergent effects on rates of violent crime, suggesting that all gun availability may not have the same effect on crime rates. More specifically, illegally obtained guns may be more likely to be used during the course of a violent crime, whereas legally obtained weapons may

be more salient in a defensive context or have no relationship to criminal violence at all (Stolzenberg & D'Alessio, 2000). The availability of legal firearms may also have a greater influence on shootings that occur in the home, such as incidents between intimate partners, but have few effects for street violence-related shootings (Stansfield et al., 2021; Stansfield & Semenza, 2019). Given very limited research that examines these two types of gun availability alongside one another, however, it remains difficult to determine the different effects they may have for rates of homicide.

Illegal Versus Legal Firearm Availability

Individuals embedded in high-risk social networks frequently commit gun violence using illegal firearms acquired by informal trade, theft, and diversion from legal firearms sales (Braga et al., 2020; Cook et al., 2007; Papachristos et al., 2013). Illegal guns used in the course of crimes are highly likely to be acquired through "street" resources such as drug dealers, fences, illicit gun dealers, or gang associates (Cook et al., 2015; Hureau & Braga, 2018). According to one estimate, more than 250,000 guns are stolen each year and a portion of these guns are later used in the commission of a violent crime (Langton, 2012). Gun traffickers also divert firearms from legal commerce into illegal channels through trafficking pathways including gun shows, flea markets, want ads, negligent dealers, and "straw man" purchases (Chesnut et al., 2017). Illicit guns are often transported from states with less restrictive gun laws into underground markets within more heavily regulated states (Braga et al., 2020). Since illegal guns are prevalent among small networks of high-risk individuals that drive rates of gun violence in U.S. cities, this illegal supply likely represents a crucial intervention opportunity for homicide reduction (Hureau & Braga, 2018).

Despite research that has identified firearm trafficking patterns (Braga et al., 2012; Wintemute et al., 2005), classified the means by which criminals steal and acquire illicit guns (Braga et al., 2020; Cook et al., 2007), and disentangled the economic dynamics of illicit gun markets among those in high-risk networks (Hureau & Braga, 2018), there is relatively little research on how the general availability of illegal guns impacts rates of gun violence in cities. In one study, Dierenfeldt et al. (2017) found that illegal gun availability, measured as the rate of firearm theft incidents reported to police using NIBRS data, was positively associated with expressive gun crimes and robberies in a sample of 189 U.S. cities over 4 years. Stolzenberg and D'Alessio (2000) similarly uncovered an association between illegal gun availability (operationalized as the number of guns reported stolen to law enforcement) and gun violence in counties across South Carolina. Yu et al. (2020) found that illegal firearm availability is a robust predictor of the number of shootings in neighborhoods in Newark, New Jersey. In a final study, Stansfield and colleagues (2021) found that illegal firearm access in cities corresponds to firearm homicides between non-intimate associates. Together, this body of work suggest that the availability of illegal guns influences violent crime rates.

Researchers have also analyzed how the availability of legal firearms corresponds to violent crime rates. Recently, Haviland et al. (2021) determined that the per-capita rate of FFLs is one of the strongest proxies for measuring firearm availability when compared to survey data of firearm ownership. Researchers posit at least two reasons for why legal firearm availability should influence rates of violent crime with particular attention to FFLs. First, firearm dealers may act similarly to institutions such as bars or nightclubs that increase crime because they provide suitable targets for victimization, serve as physical signals of social disorganization, and directly encourage criminal behavior (Kubrin et al., 2011). In support of this perspective, Steidley and colleagues (2017) found that a greater number of local gun stores was associated with neighborhood homicide and robbery across 89 U.S. cities, with pronounced effects in neighborhoods with greater levels of residential instability.

On the other hand, the density of legal firearm dealers may be associated with increased gun violence in communities not due to their physical location but because they are a local resource for the acquisition of weapons used for lethal violence (Semenza et al., 2020). This view posits that despite the fact that guns may be acquired legally through FFLs, a greater concentration of gun stores nonetheless contributes to the general availability of firearms used for violence in the community. To illustrate, researchers have found that a higher concentration of firearm dealers in urban counties is associated with the risk for both total and intimate partner homicides with a firearm (Semenza et al., 2020; Stansfield et al., 2021; Wiebe et al., 2009).

Despite growing evidence that access to guns measured via FFL density corresponds to heightened rates of gun violence, the results are less straightforward when considering other proxies of legal availability and concurrent illegal access. For instance, Stolzenberg and D'Alessio (2000) found that a different proxy of legal gun availability (county-level rate of concealed carry permits in South Carolina) was *not* associated with violent crime after accounting for illegal availability. Matthay et al. (2021) similarly did not find a statistically significant relationship between newly opened firearm dealers and localized firearm injuries across zip codes in California. These mixed findings suggest a need for continued research that accounts for both illegal and legal availability specifically using FFL density as a proxy for legitimate firearm access to further explore the availability-homicide link.

The Context Of Economic Disadvantage

One of the most important community factors to consider regarding the association between firearm availability and violent crime is the context of economic disadvantage. Any association between firearm availability and homicide may be conditional upon the level of structural disadvantage in cities, including heightened poverty, unemployment, income inequality, and residential segregation (Parker et al., 2005; Sampson et al., 1997). Structural economic disadvantage is consistently associated with higher rates of violence and homicide (Friedson & Sharkey, 2015; Kubrin & Weitzer, 2003; Parker et al., 2005) and much of the research on firearm availability and

gun violence has established this relationship predominantly in urban communities that experience significant disadvantage.

It is plausible that both illegal and legal firearm availability should contribute to increased gun violence disproportionately in disadvantaged cities. First, weakened informal and formal social controls in disadvantaged communities may enable illicit gun markets to proliferate more so than in places with stronger social controls (Braga et al., 2002; Hureau & Braga, 2018). For example, disadvantaged communities often suffer from a lack of collective efficacy, a form of informal social control linked to reduced community violence (Sampson et al., 1997). Likewise, the effectiveness of formal social controls, such as policing, may be reduced in communities with significant structural disadvantage (Sampson & Groves, 1989). Reductions in formal social control may enable illegal gun markets to flourish more widely, creating easier access to firearms among high-risk networks of offenders that drive much of a city's gun violence (Cook et al., 2007). Disadvantaged communities are also more likely to suffer from disproportionately punitive social controls related to over-policing and poor community-police relationships (Schafer et al., 2003). These dynamics may create greater demand for illegal firearms in disadvantaged communities, driven by a lack of trust in the police, and reliance on informal strategies of self-policing and "street justice" that further fuel rates of gun violence (Kubrin & Weitzer, 2003). In either scenario (too much or too little social control), incentives to seek guns from illegal gun markets in disadvantaged communities may be heightened.

Gun shops in disadvantaged locales may also influence violent crime by directly leading to greater risk of victimization in their vicinities or indirectly sending signals of social disorganization (Steidley et al., 2017). In the same way that payday lenders, bars, and night clubs can function as hot spots for crime in disadvantaged areas (Kubrin et al., 2011), local gun shops may serve as similar violent locales. Firearms retailers in highly disadvantaged areas may also disproportionately act as scofflaw dealers (Braga et al., 2002), or operate as high-risk dealers that provide guns later used in the commission of a crime (Wintemute et al., 2005). In sum, the concentration of legal firearm dealers and the availability of illegal firearms within particularly disadvantaged communities, and cities more broadly, both may influence rates of homicide.

Current Study

Understanding the dynamics of how legal and illegal firearm availability correspond to rates of gun violence is crucial for establishing actionable policies to reduce gun violence. Yet, mixed results from prior research necessitate greater clarity on the subject, especially concerning how gun availability influences rates of homicide across gradients of structural disadvantage. Thus, we set out to accomplish the following objectives: (1) examine the relationship between both illegal and legal firearm availability and rates of homicide year-over-year across cities in the U.S., and (2) assess how structural economic disadvantage in cities conditions the relationship between each type of firearm availability and homicide rates.

Method

Data

We combined several data sources to create a city-level panel dataset with annual observations from 2010 to 2017. First, we obtained homicide data from the FBI's Supplemental Homicide Report (SHR) that contains information on both circumstances and weapon type used. Second, data on legal gun availability come from the number of federally licensed firearm dealers in a city. The data come from the ATF's FFL Listing, which provides a complete list of FFLs and their locations in the U.S.[1] Third, we utilize data from The Trace's "Missing Pieces" database, which combines over 800,000 records on guns reported lost, stolen, or recovered by law enforcement agencies in major cities and counties in 36 states. The Trace is an independent nonprofit news organization that compiled the data on gun recoveries through public records requests.[2] Finally, we collected city-level economic and demographic data from the American Communities Survey (ACS) available through the National Historical Geographic Information System (NHGIS).

The final sample includes 226 cities from 30 different states. We arrived at this sample based on the availability of agencies in the "Missing Pieces" database ($n = 1{,}021$) and included cities that had a minimum population of 50,000. Since the sample of cities in the Trace database is not random, we included all cities with a population above 50,000 to ensure an adequate sample size with cities experiencing sufficient counts of homicide. Cities under 50,000 were excluded due to low occurrence of gun homicide and because prior studies have suggested that our measure of legal gun availability is a relatively weak proxy for gun ownership in smaller and more rural populations (Haviland et al., 2021; Wiebe et al., 2009).

We note that the "Missing Pieces" dataset includes almost complete coverage for agencies in California and Florida (755 of the 1,021 agencies), in addition to large population centers from 30 different states and Washington, D.C. Given the coverage of Florida and California, many of the cities in our data with populations between 50,000 and 100,000 came from one of these two states. To ensure the final results were not driven by these states alone, we re-estimated all models using only cities with a minimum population of 100,000 (thereby excluding many of the mid-sized cities from California and Florida). Substantive results remained consistent and are available upon request.

Measures

We generated two dependent variables from the SHR data—the count of firearm homicides and the count of homicides not perpetrated with a firearm. To control for broader violence irrespective of gun availability, models estimating firearm homicides in the U.S. include the non-firearm homicide rate (log transformed) as a control variable. Similarly, models estimating non-firearm homicides control for the gun homicide rate. Notably, however, the substantive results reported here were not sensitive to the inclusion or exclusion of this control variable.

Our key explanatory variables represent two types of firearm availability. To approximate illegal availability, we include the rate (per 1,000 of the population) of guns reported lost or stolen. Although we acknowledge that this measure is a proxy of illegal availability since many illicit firearms are unknown to the police, prior studies of illegal gun availability have used similar measures (Dierenfeldt et al., 2017; Stolzenberg & D'Alessio, 2000). Following past research (Steidley et al., 2017; Semenza et al., 2020), we measure legal availability as the rate of FFLs per 100,000 of the population. The rate of FFLs is significantly correlated with another commonly used measure of firearm availability, the proportion of suicides committed with a gun (FS/S), specifically in cities (Wiebe et al., 2009). FFL density has also been found to be a strong proxy for firearm access when compared to firearm ownership surveys, particularly in urban counties (Haviland et al., 2021). Although the overall number of FFLs in a city can indicate the broad prevalence of legal firearms in an area, it is also possible that specific types of firearm dealers may affect firearm availability differently (Steidley et al., 2017). As such, we include measures of Type I (local gun dealers) and Type II (pawnbroker) FFLs. Furthermore, we assess differences for licensed dealers of firearms (Type I) using a separate category for "big box" dealers.[3] Data on gun stores were aggregated to the city level for each year in our study based on the store's address.

The indicators of economic disadvantage used here are common in the homicide literature (McCall et al., 2013). First, we constructed a weighted economic disadvantage scale by conducting a principal components factor analysis of four different indicators including: the percentage of families in poverty; the percentage of family households headed by a female; the percentage of the population in the labor force who are unemployed; and the median income household income (log transformed prior to inclusion in the factor analysis; Eigenvalue = 2.919). In general, our sample was slightly below the national average for measures of disadvantage, with an average poverty rate of 10.7%. This varied across our sample, however, with an average poverty rate of 12% in cities with above 100,000 in population and 14.6% in cities with a population more than 500,000.

We do not include measures of race and ethnicity composition (percentage Black, percentage non-Black Hispanic) in our index of disadvantage so that we could estimate the direct influence of race and ethnicity on firearm homicide over time as in prior studies (Stults & Hasbrouck, 2015; Wiebe et al., 2009; Zeoli & Webster, 2010). We encountered no issues of multicollinearity keeping these measures separate in our models.

We include an index of gun laws for each state in our data set based on comprehensive data collected by researchers at Boston University (statefirearmlaws.org). The database catalogs 133 firearm law provisions for all 50 states from 1991 through 2020 across 14 categories of provision types (McClenathan et al., 2017). The index used here measures the total number of laws in each state for our analysis between 2010 and 2017 including: requirements for dealers to have a state license, bans on non-commercial dealers, mandatory theft reporting, mandatory minimum waiting periods, license or permit requirements, gun registration requirements, background check requirements,

Table 1. Descriptive Statistics ($N = 226$ Cities).

	Mean	Overall *SD*	Between *SD*	Within *SD*
Firearm homicide count	12.741	39.208	35.433	7.931
Non-firearm homicide count	4.113	10.072	9.386	2.399
Firearm homicide rate (lg)	1.211	0.973	0.847	0.482
Non-firearm homicide rate (lg)	0.788	0.674	0.493	0.486
Lost/stolen gun rate (×1,000)	0.581	0.757	0.644	0.309
Total store rate (×100,000)	12.164	13.873	13.775	3.678
Big box store rate	1.201	1.314	1.279	0.370
Other FFL I rate	8.302	8.546	8.827	1.857
FFL II rate	2.025	3.477	3.416	0.800
Economic disadvantage	0.000	0.970	0.967	0.090
% Poverty	10.692	6.137	6.095	0.775
% Female headed households	11.658	5.157	5.092	0.853
% Unemployed	8.825	4.078	3.209	2.520
Median income ($)	69,181.92	25,598.15	25,457.31	2,930.89
% Black	12.558	14.673	13.999	0.699
% Hispanic	29.340	21.613	22.138	1.387
% Disengaged youth	3.002	2.132	1.945	0.878
% Divorced males	3.445	1.081	1.195	0.179
Police force size (lg)	5.266	0.813	0.841	0.062
South	0.199	0.399		
West	0.539	0.498		
Gun law index	14.170	9.342		

gun trafficking prohibitions, and straw purchase laws. The final index is a count of 0–23 laws for all types of firearms, reflecting the general level of legal stringency for gun regulation for each state.

Finally, we account for several additional control measures including a time-variant measure of police force size, operationalized as the number of full-time sworn officers in each city (per 100,000 of the population, log transformed). We also include the percentage of youth ages 16 to 19 not currently in school or in the labor force to account for the broader risk of youth participation in violence (Dollar et al., 2017; McCall et al., 2013). We include the percentage of men ages 16 and older that were divorced, a consistent correlate of homicide and violence (Pratt & Cullen, 2005).[4] Finally, all models include regional controls for location in the South and West, as well as year fixed effects. Table 1 displays summary descriptive statistics for all measures used in our analysis.

Analytic Strategy

We estimate random effects negative binomial regression models to assess the association between firearm availability and gun violence, controlling for important time

variant and invariant factors associated with homicide (Rabe-Hesketh & Skrondal, 2008). This approach accounts for the correlation of observations over time and within cities (Hilbe, 2011). Negative binomial models were preferred over alternatives (such as Poisson regression) given that the standard deviation for gun homicides was more than three times the mean ($M = 12.74$, $SD = 39.21$).[5] Several cities in our sample did not have complete data on illegal gun availability for 2017 so the total number of cases in our final sample was 1,682. Due to the relatively large number of cities (226) but comparatively short time span (8 years) available in our data, in addition to low within-unit variation for several key predictors such as FFL rates, a random effects model was preferable over a fixed effects approach (Stowell et al., 2009; Stults & Hasbrouck, 2015). Furthermore, we expect differences across cities to exert influence on gun homicide given legal and cultural variation in gun ownership across the U.S. Thus, the coefficients presented here are weighted scores of between-city and within-city estimates. The reported standard errors are clustered at the state level, although they were ultimately very similar to traditional estimates.

As a common solution to concerns of simultaneity and reverse causation (Peters et al., 2017), we estimated all models using lagged variables such that the gun availability measures and other covariates are lagged 1 year behind homicides. Prior to multivariate analysis, we examined bivariate correlations between all independent variables (see Appendix A1). Items were initially entered into models one at a time to ensure that directions and magnitudes of coefficients did not change abruptly and no indication of multicollinearity was detected.

In our multivariate analysis, we first estimate the relationship between illegal and legal firearm availability and each firearm and non-firearm homicide, controlling for all pertinent correlates. We also consider whether legal gun availability has different effects based on the type of FFL: (1) big box stores, (2) all Type I FFLs excluding big box stores, and (3) Type II FFLs (pawnbrokers). We then estimate each model with the addition of interaction terms to assess whether the gun availability–firearm homicide link is moderated by city-level disadvantage. All analyses were carried out in Stata 16.

Results

Table 2 presents the results of the multivariate models estimating firearm and non-firearm homicide rates. Models 1 and 2 indicate a significant relationship between illegal firearm availability and firearm homicide, controlling for all correlates. Legal firearm availability via the FFL rate is not associated with firearm homicides in either model. Additionally, greater economic disadvantage, the rate of non-firearm homicide, and the percentage of the population that is Black are all associated with an increased incidence of firearm homicide, consistent with existing literature (Zeoli & Webster, 2010).[6] The index of state-level firearm laws is not significantly associated with firearm homicides, although it does correspond to greater non-firearm homicide.[7] Although higher rates of illegal firearm availability are associated with more firearm homicides over the study period, neither the rate of illegal firearm availability nor the

Table 2. Random Effects Negative Binomial Regression Estimating Firearm and Non-Firearm Homicide.

	Firearm homicide				Non-firearm homicide			
	Model 1		Model 2		Model 3		Model 4	
	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI
Illegal availability	1.147***	[1.067, 1.234]	1.133**	[1.053, 1.219]	1.024	[0.961, 1.092]	1.024	[0.960, 1.093]
Total FFL rate	1.005	[0.997, 1.011]			0.997	[0.992, 1.002]		
FFL 1			0.998	[0.986, 1.011]			1.002	[0.992, 1.011]
Big box			1.086	[1.000, 1.167]			0.965	[0.909, 1.024]
FFL2			1.003	[0.972, 1.035]			0.996	[0.974, 1.019]
Disadvantage	1.383**	[1.133, 1.688]	1.321**	[1.073, 1.627]	1.215**	[1.086, 1.360]	1.197**	[1.068, 1.342]
Non-firearm homicide	1.088*	[1.018, 1.162]	1.095**	[1.023, 1.172]				
Firearm homicide					1.409***	[1.297, 1.530]	1.405***	[1.293, 1.528]
Firearm law index	1.009	[0.991, 1.026]	1.007	[0.989, 1.025]	1.017**	[1.006, 1.028]	1.016**	[1.005, 1.027]
% Black	1.030***	[1.019, 1.041]	1.030***	[1.019, 1.042]	1.000	[0.994, 1.006]	1.001	[0.994, 1.007]
% Hispanic	1.001	[0.994, 1.009]	1.004	[0.996, 1.012]	1.000	[0.996, 1.004]	1.001	[0.996, 1.005]
% Divorced	1.067	[0.948, 1.201]	1.059	[0.935, 1.199]	1.140***	[1.060, 1.226]	1.137**	[1.055, 1.226]
Police size	0.928	[0.797, 1.080]	0.923	[0.781, 1.091]	1.060	[0.990, 1.136]	1.057	[0.985, 1.135]
Disengaged youth	1.000	[0.959, 1.043]	0.994	[0.952, 1.037]	1.028	[0.992, 1.064]	1.027	[0.991, 1.064]
South	0.760	[0.525, 1.098]	0.743	[0.505, 1.094]	1.112	[0.927, 1.333]	1.096	[0.908, 1.322]
West	0.921	[0.583, 1.457]	0.863	[0.538, 1.383]	0.845	[0.678, 1.053]	0.857	[0.687, 1.069]
Chi^2	241.74		227.57		525.00		515.92	
Observations	226		226		226		226	

Note. All models include year fixed effects.
*$p < .05$. **$p < .01$. ***$p < .001$.

Table 3. Interaction Effects of Economic Disadvantage and Firearm Availability Estimating Firearm Homicide.

	Model 1		Model 2	
	IRR	95% CI	IRR	95% CI
Illegal availability	1.060	[0.944, 1.192]	1.153***	[1.072, 1.240]
Total FFL rate	1.003	[0.996, 1.009]	0.999	[0.990, 1.009]
Illegal availability × disadvantage	1.151*	[1.001, 1.336]		
Total FFL rate × disadvantage			1.007	[0.997, 1.017]
Disadvantage	1.333**	[1.100, 1.616]	1.297*	[1.043, 1.615]
Non-firearm homicide	1.091**	[1.023, 1.163]	1.086*	[1.016, 1.161]
Firearm law index	1.008	[0.991, 1.025]	1.008	[0.991, 1.026]
% Black	1.030***	[1.020, 1.040]	1.029***	[1.019, 1.041]
% Hispanic	1.002	[0.992, 1.012]	1.002	[0.994, 1.010]
% Divorced	1.076	[0.932, 1.242]	1.077	[0.957, 1.213]
Police size	0.921	[0.774, 1.097]	0.921	[0.791, 1.072]
Disengaged youth	0.997	[0.943, 1.055]	1.002	[0.961, 1.045]
South	0.754	[0.520, 1.094]	0.752	[0.521, 1.086]
West	0.923	[0.631, 1.350]	0.896	[0.568, 1.413]
Chi^2	250.35		247.07	
Observations	226		226	

Note. All models include year fixed effects.
*$p < .05$. **$p < .01$. ***$p < .001$.

rate of FFLs is associated with non-firearm homicide. Models 3 and 4 provide further evidence of the persistent effects of economic disadvantage on homicide, in addition to family disruption, which is significantly associated with higher rates of non-firearm homicide in both models.

Estimates presented in Table 3 assess whether economic disadvantage moderates the association between firearm availability and gun homicide. Model 1 introduces an interaction between illegal availability and economic disadvantage. The IRR for the interaction term indicates that the association between firearm availability and gun homicide is greater in cities with higher economic disadvantage. Furthermore, the coefficient for illegal availability is no longer significant, suggesting that the association between illegal availability and firearm homicide is fully conditional upon level of economic disadvantage, but not significant in cities with below-median levels of disadvantage. To illustrate, we estimated separate models for cities in the highest third of disadvantage. Among these 77 cities, an increase in illegal availability was associated for a 23% increase in gun homicides (IRR = 1.238, CI [1.105, 1.386]), whereas in the less disadvantaged 149 cities, confidence intervals contained the value of 1, demonstrating that the association is not statistically significant (IRR = 1.103, CI [0.983, 1.238]).

Model 2 introduced an interaction between disadvantage and the total FFL rate, but a non-significant interaction term suggests that disadvantage does not moderate the association between FFLs and gun homicide. Greater illegal availability and economic disadvantage both retained associations with gun homicide. We also estimated interactions separately for each of the gun dealer types (not shown). These interactions did indicate a positive interaction between Type 1 dealers and economic disadvantage whereby a higher rate of these FFLs was associated with firearm homicide in cities with higher levels of economic disadvantage ($p < .01$). Given extremely wide confidence intervals produced by this analysis, however, we caution that our study is not powered to make conclusions based on these interactions.

Ancillary Analyses

We conducted supplementary analyses to confirm the validity of our main results. Since only one other study to our knowledge has used the Trace's Missing Pieces data (Stansfield et al., 2021), we sought to examine the data's comparability with three other measures of illegal availability. First, the measure chosen for our main analysis includes guns lost and stolen as in prior studies (e.g., Stolzenberg & D'Alessio, 2000). However, the Trace also reports the number of guns recovered by police that were *not* previously stolen. Although guns recovered by the police may reflect variation in police priorities and seizure behaviors, it could also indicate additional supplies of illegal guns in local communities. We therefore re-estimated the main models from Table 2 using this expanded measure of all guns reported lost, stolen, or recovered by the police.

Second, the Uniform Crime Report program reports the annual value of guns stolen each year by police agency. Although the value does not necessarily represent the total number of guns (Stolzenberg & D'Alessio, 2000), others have used the value of recovered guns as a percentage of all stolen property as a proxy for illegal availability (Kleck & Patterson, 1993). Finally, data from NIBRS have also been used to assess illegal gun availability (Dierenfeldt et al., 2017; Stolzenberg & D'Alessio, 2000). NIBRS data were not available for as many of the cities in our main dataset as the other measures (only 112 matched), including no data available for California. Nevertheless, we assessed whether our results were consistent in this smaller sample with the same measure of illegal guns from NIBRS as used by others (Dierenfeldt et al., 2017), an incidence rate for firearms stolen per 100,000. As revealed in Appendix A2, each of these additional measures performed consistently with our main displayed results such that illegal availability is associated with subsequent firearm homicide irrespective of the measure of illegal availability employed. On the other hand, the rate of FFLs is not associated with firearm homicide when accounting for these measures of illegal availability.

Discussion

In this study, we examined how legal and illegal firearm availability concurrently influence year-over-year rates of homicide across U.S. cities. We also assessed how

these relationships differ by the context of city-wide economic disadvantage. The results produced three key findings. First, illegal firearm availability, measured as the rate of lost or stolen firearms in a city, was associated with an increase in firearm homicide. Importantly, this measure was not associated with non-firearm homicide rates. Robustness checks using multiple proxies for illegal firearm availability across different samples of cities confirmed the association between illegal availability and rates of firearm homicide. Second, legal firearm availability, measured as the rate of FFLs across three different types of dealers, was not associated with firearm homicide when simultaneously accounting for illegal availability. Third, illegal availability of firearms was found to correspond to increased rates of firearm homicide in cities characterized by greater economic disadvantage. In fact, the influence of illegal availability on firearm homicide appears to be contingent on economic disadvantage since our measure of illegal availability was no longer significant when the interaction with disadvantage was included in the model.

These findings support a need for further efforts to reduce gun violence by limiting the availability of illegal firearms in the U.S. The results of the interaction tests between economic disadvantage and firearm availability support previous studies demonstrating that gun availability is more consequential for firearm homicide where economic disadvantage is greater (Altheimer, 2008; McDowall, 1991; Yu et al., 2020). In fact, it appears that illegal availability has an outsize influence on rates of homicide in high-disadvantage cities. We anticipated that disadvantage might augment the negative effects of illegal firearm availability through declines in both informal and formal social control (Sampson & Groves, 1989; Sampson et al., 1997). Although our results are consistent with this explanation, further research is needed to confirm these mechanisms.

We speculate that illegal firearms are more often sought in accordance with risky and criminal behavior, whereas legal guns may be more likely to be possessed without criminal intent (Braga et al., 2002; Hureau & Braga, 2018). Disadvantaged communities with lower levels of social control (both formal and informal) may be more likely to render risky behaviors more dangerous and lead to greater incidence of violence via greater demand for illegal guns. This implies that illegal supplies of firearms should remain a key focus for violence reduction in high-disadvantage areas. Still, articulating why these effects are exacerbated in disadvantaged areas warrants further investigation to produce viable policy recommendations, especially as law enforcement often views gun possession (legal or illegal) as more problematic in disadvantaged communities of color (Carlson, 2019). Efforts such as hot-spot policing may prove useful to immediately address illegal weapon availability, yet we caution that law enforcement should not conflate race and place with inherit illegality (Braga & Pierce, 2005; Peterson & Krivo, 2010).

According to Braga et al. (2020), targeting high-volume gun brokers and intermittent illegal transactions via straw purchases may be especially fruitful avenues for reducing the influx of legal guns into underground markets. However, it is crucial to consider the broad state-level contexts in which disadvantaged cities are embedded

given that states with non-restrictive gun laws tend to have an outsize influence on illegal markets in cities within more legally restrictive states. Thus, efforts to concurrently (a) reduce the primary influx of legal firearms into underground markets through stronger gun laws and gun store regulations, and (b) target pre-existing illicit market players at multiple levels (e.g., major brokers, middlemen, and one-time suppliers) may be an effective framework for reducing shootings by limiting illicit firearm supplies.

Study Limitations and Future Research

This study entails certain limitations that present opportunities for continued research. First, given the use of the Missing Pieces data to measure illegal firearm recoveries, we were not able to assess the prevalence of illegal firearms in all U.S. cities. While we were able to include cities from most states, future studies should continue to work toward full national representation to ensure that our findings are robust and replicable. Second, although we leverage a time-ordered analytic approach, we caution against causal claims until more consistent longitudinal data are available to fully test all mechanisms in the processes discussed here.

Third, our measures for illegal and legal gun availability are necessarily proxies. There are certainly illegal guns in cities that are never recovered by law enforcement, yet our primary measure represents an initial step in assessing macro-level measurement of illegal firearm prevalence. The robustness checks using both UCR and NIBRS data provide validation that the results of the main analysis hold up using various proxies and samples of U.S. cities. Likewise, although the presence of FFLs has been shown to be one of the strongest proxies for firearm ownership especially in cities (Haviland et al., 2021), it likely does not reflect gun availability as accurately where existing gun ownership levels are already high. A true measure of firearm prevalence can only be obtained through nationally representative survey data or a comprehensive repository of gun ownership data similar to motor vehicle licensing in the U.S. (Thiels et al., 2018). Such limitations remain endemic to firearms research (Fridel, 2020a, 2020b), underscoring the need for improved and comprehensive data collection regarding firearm ownership and gun violence incidence.

Despite these limitations, this study contributes to a greater understanding of how different types of firearm availability influence violent crime across cities in the U.S. The results provide support for gun violence reduction strategies that limit the supply of illegal guns through numerous channels. A comprehensive approach to violence reduction requires improvements in firearms tracking, tracing, and data collection at a national level. As tens of thousands of people continue to lose their lives each year, particularly in the country's most vulnerable communities, continued research and evaluation of promising interventions remain crucial to address the urgent issue of American gun violence.

Appendix

A1. Correlation Matrix of Key Variables of Interest.

	1	2	3	4	5	6	7
1. Firearm homicide rate (ln)	1.00						
2. Non-firearm homicide rate (ln)	0.53	1.00					
3. Illegal gun availability	0.25	0.19	1.00				
4. Total FFL rate	0.04	0.05	0.18	1.00			
5. Big box store rate	−0.01	−0.03	0.20	0.76	1.00		
6. Other Type I dealer rate	0.02	0.03	0.15	0.97	0.68	1.00	
7. Type II dealer (Pawnbrokers)	0.12	0.11	0.18	0.80	0.58	0.64	1.00

A2. Robustness Checks w/Alternate Measures of Illegal Gun Availability to Estimate Firearm Homicide.

	Lost/stolen and recovered		% Value of stolen guns		Stolen gun incidents	
	(The Trace)		(UCR)		(NIBRS)	
	IRR	95% CI	IRR	95% CI	IRR	95% CI
Illegal availability	1.047**	[1.018, 1.075]	1.042*	[1.009, 1.076]	1.263***	[1.139, 1.402]
Total FFL rate	1.002	[0.996, 1.009]	1.012	[0.950, 1.077]	0.948	[0.879, 1.022]
N	226		282		113	
Chi^2	315.46		546.36		653.79	

Note. All models are fully controlled as in main analyses.
*$p < .05$. **$p < .01$. ***$p < .001$.

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Notes

1. FFL data for 2014-2017 were obtained from the from ATF website (https://www.atf.gov/firearms/listing-federal-firearms-licensees). FFL data from 2010 to 2013 were obtained similarly, but the ATF website has since removed these records. FFL data for all years are available upon request.
2. The Missing Pieces data were compiled with the assistance of more than a dozen NBC TV stations, who along with the editors at the Trace, obtained data by filing public records requests in the property and evidence-management systems of major cities around the U.S. All firearms stolen and recovered were included here.
3. To create a measure of big-box store rates we followed [Identifying reference, 2017] and searched the ATF FFL listings for duplicate Type I FFL holders belonging to corporations (such as Walmart, Bass Pro Shops, and Cabela's) and coded these listings as big box stores. This measure for big box stores was coded to be mutually exclusive from all other Type I FFLs.
4. We tested whether controlling for additional crime measures, such as the total assault and property crime rates, altered our findings. No substantive differences emerged, although each crime measure was significantly and positively associated with the firearm homicide rate as expected.
5. We also estimated all models using log-transformed rates of firearm- and non-firearm homicide as dependent variables. The results pertaining to illegal availability were substantively similar to the main models and are available from the authors upon request.
6. One assumption of our approach is that the within-city effect is approximately equal in magnitude to the between-city effect. In assessing the equality assumption for models estimating firearm homicide, the Hausman test was significant. To account for this, a "hybrid" model was estimated where we separated the between (time invariant) and within (time variant) effects of predictors and included those as distinct effects. Both components were consistent across predictors (Raudenbush & Bryk, 2002). Since these decomposed models complicate the analysis that explores interaction effects, we report the simpler models.
7. In supplementary analyses, we found that illegal firearm availability's association with firearm homicide is moderated by legal stringency such that the association was most prevalent in states with lower than median number of gun laws. This is worthy of further investigation in future research but is not the focus of the present study.

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