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Guns and Crime

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We estimate several models of handguns and crime based on state-level panel data for 1977–1998 using both General Social Survey data on gun availability and a new measure of handgun prevalence. We find that handguns have a negligible effect on crime. Apparently, there is either no causation between guns and crime, or a rough equilibrium between criminals who use guns in the commission of crime and ordinary citizens who use guns to defend themselves and deter crime.

JEL Classification: K42

1. Introduction

Guns make crime easier to commit. Armed criminals are more easily able to secure victim cooperation. Guns also make it easier to commit larger scale crimes, such as bank robbery. More guns, therefore, can increase the number of criminals and encourage current criminals to be more active. Also, more guns in homes can encourage burglary, since guns are valuable loot (Cook and Ludwig 2003).

On the other hand, people also acquire and use guns for self-defense. Cook and Ludwig (1997) estimate that 14 million people carried firearms for protection during the year prior to the survey (p. 8) and used them defensively at least 500,000 times.[1] Criminals typically do not want to confront armed victims. Wright and Rossi (1986) report that one-third of the career criminals they interviewed reported being "scared off, shot at, wounded, or captured by an armed victim" (p. 15). Because criminals often do not know whether a potential victim is armed, they may be deterred from committing any crime involving face to face contact. Thus, gun carrying by ordinary citizens can reduce crime even against those who are not armed (Lott and Mustard 1997; Lott 2001). So, do guns cause more or less crime?

A number of studies have examined the relationship between gun availability and crime (e.g., Kleck and Patterson 1993; Duggan 2001; Cook and Ludwig 2003; see Kleck, 1997, pp. 215–61 for a review). This research encounters two difficult methodological issues: the simultaneity discussed above and the difficulty in measuring gun availability. We address the simultaneity issue using Granger causality tests and simultaneous equation models with valid identifying restrictions. Previous studies have addressed the problem of measuring gun levels by constructing proxy variables. We use a new measure of gun availability based on the General Social Survey, the only direct measure of gun prevalence.

In the next section we outline a simultaneous equation model of crime, guns, and sanctions. In Section 3 we discuss the data and data problems associated with gun prevalence, and we describe the development of a new measure of guns. Section 4 describes the econometric methods employed in our

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[1] A survey by Kleck and Gertz (1995) estimates 2.5 million incidents of defensive gun use annually.

analysis of various dynamic panel data models. The results of the analyses are reported in Section 5. Section 6 discusses the issue of possible attenuation bias due to errors in variables. Section 7 summarizes and concludes the article.

2. Theory

We assume that crime is a function of guns and sanctions. The theoretical signs on the partial derivatives are subject to some dispute. Guns could cause crime because as guns become more prevalent, more will fall into the hands of criminals through loss and theft (Cook and Ludwig 2003). More guns could also lead to an escalation of violence, making crime more likely and more serious (Duggan 2001). On the other hand, Lott and Mustard (1997) find that the passage of right-to-carry concealed weapons laws, which presumably increases the number of guns, both at home and in public, reduces crime. It is entirely possible that both arguments are correct, in which case the net effect of guns on crime could be positive, negative, or zero. Similarly, both arguments could be wrong and guns are completely independent of crime, yielding a zero coefficient on guns in the crime equation. Thus, the sign of the partial derivative of guns in the crime equation remains an empirical question. Crime can also cause ordinary citizens to acquire guns for self-defense. Thus we would expect that the partial derivative of crime in the gun equation is positive.

Society attempts to control crime through the use of sanctions. The criminal justice system includes the police who investigate crime and make arrests, prosecutors and judges who try the accused and sentence the guilty, and prisons where convicted felons are incarcerated. It is generally recognized that prisons reduce crime due to a combination of incarceration and deterrent effects (e.g., Levitt 1996; Marvell and Moody 1994, 1997, 1998). We would therefore expect a negative partial derivative on prison in the crime equation. We expect that crime is negatively related to arrests, arrests are a positive function of crime, and that prisons are positively related to arrests. We assume that arrests and the prison population are independent of the level of guns except indirectly through possible impacts on crime.[2] Assuming a linear model, the specification is as follows:

$$\begin{aligned} C &= \alpha_0 + \alpha_1 P + \alpha_2 G + \alpha_3 A + \alpha_4 \boldsymbol{Z_C} \\ P &= \beta_0 + \beta_1 C + \beta_2 A + \beta_3 \boldsymbol{Z_P} \\ G &= \gamma_0 + \gamma_1 C + \gamma_2 \boldsymbol{Z_G} \\ A &= \delta_0 + \delta_1 C + \delta_2 \boldsymbol{Z_A}, \end{aligned}$$

where C is crime, P is prison incarceration, G is gun availability, A is arrests; $\boldsymbol{Z_C}$, $\boldsymbol{Z_P}$, $\boldsymbol{Z_G}$, and $\boldsymbol{Z_A}$ are vectors of exogenous variables, and $\alpha_1 < 0$, $\alpha_3 < 0$, $\beta_1 > 0$, $\beta_2 > 0$, $\gamma_1 > 0$, $\delta_1 > 0$. The sign of α_2 is not known a priori.

Treatment of the Arrest Variable

Crime and arrests could be simultaneously determined. If so, it is notoriously difficult to identify the coefficient on arrests in the crime equation because the same factors that increase crime will also increase arrests (Fisher and Nagin 1978). Criminologists have taken a variety of approaches to address this problem. Some include the arrest variable and estimate using ordinary least squares (Lott and Mustard 1997; Mustard 2003); others estimate a simultaneous model, despite the identification

[2] An anonymous referee has suggested that guns might by substituted for sanctions by people who are substituting private deterrence for social sanctions. We can find no empirical support for this interesting hypothesis.

problem (Ehrlich 1973; Lott and Mustard 1997); while others (Levitt 1996; Marvell and Moody 1994, 1997, 1998) drop the arrest variable entirely.[3] If we drop the arrest variable, what does this imply for the coefficients on prison and guns? To see the effect, we solve for arrests, yielding the following set of equations:

$$\begin{aligned} C &= \left(\frac{\alpha_0 + \alpha_3\delta_0}{1-\alpha_3\delta_1}\right) + \left(\frac{\alpha_1}{1-\alpha_3\delta_1}\right)P + \left(\frac{\alpha_2}{1-\alpha_3\delta_1}\right)G + \left(\frac{\alpha_3\delta_2}{1-\alpha_3\delta_1}\right)\boldsymbol{Z_A} + \left(\frac{\alpha_4}{1-\alpha_3\delta_1}\right)\boldsymbol{Z_C}, \\ P &= (\beta_0 + \beta_1\delta_0) + (\beta_1 + \beta_2\delta_1)C + \beta_2\delta_2\boldsymbol{Z_A} + \beta_3\boldsymbol{Z_P}, \\ G &= \gamma_0 + \gamma_1 C + \gamma_2\boldsymbol{Z_G}. \end{aligned} \tag{1}$$

As Equation system 1 shows, the coefficients on prison and guns in the crime equation depend on the value of the product $\alpha_3\delta_1$. Since we expect that $\alpha_3 < 0$ and $\delta_1 > 0$, $1 - \alpha_3\delta_1 > 1$. Consequently, the crime equation will have a nontrivial solution and the signs of the coefficients will be preserved. The resulting equation system is

$$\begin{aligned} C &= a_0 + a_1 P + a_2 G + a_3\boldsymbol{Z_A} + a_4\boldsymbol{Z_C} \\ P &= b_0 + b_1 C + b_2\boldsymbol{Z_A} + \boldsymbol{b_3 Z_P} \\ G &= \gamma_0 + \gamma_1 C + \gamma_2\boldsymbol{Z_G}, \end{aligned}$$

where $a_1 < 0$, $b_1 > 0$, $\gamma_1 > 0$ and the sign of a_2 is undetermined. The coefficient on prison in the crime equation, $a_1 = \alpha_1/(1 - \alpha_3\delta_1)$, includes the effect of arrests on crime (α_3) and the effect of crime on arrests (δ_1). Therefore, if prison is included and arrests excluded from the crime equation, the coefficient on prison is properly interpreted as the effect of arrest, prosecution, sentencing, and imprisonment on crime. Because $1 - \alpha_3\delta_1 > 1$, the coefficient on the arrest variable will be smaller than the coefficient on arrests in the crime equation, confirming the finding of Mustard (2003). Researchers thus have their choice in including or excluding the arrest variable in crime equations.[4] In the analysis presented below we report results with arrests included. Although not reported to conserve space, we found the same results with the arrest variable excluded.

3. Data

The data set consists of observations on 50 states from 1977 to 1998. Crime is measured as violent crime (murder, rape, robbery, and assault) and burglary, the major crimes for which one is usually sentenced to prison, from the FBI uniform crime reports (FBI various years). Prison population is the average of the year-end census of the current and previous year, including prisoners temporarily housed in local jails, divided by population (Marvell and Moody 1994). Arrests are the total number of arrests for the relevant crime definition divided by the number of crimes, from the uniform crime reports.

State-level observations on gun ownership are not available. The only direct measure of gun ownership at the state level is the General Social Survey (GSS) from the National Opinion Research Center (NORC). It is the gold standard for survey measures of gun ownership according to Azrael, Cook, and Miller (2001, p. 4). NORC conducts in-person surveys of 3000 adults. If the respondent reports that there is a firearm in the house, the interviewer asks a follow-up question concerning whether

[3] Mustard (2003) finds a negative correlation between arrest rates and conviction and time served, so that omitting these two variables will result in an understatement of the effect of arrests on crime. Levitt (1996) includes police as a sanction variable in his crime equation.

[4] Similarly, the prison variable can be omitted from the crime equation with the arrest variable included. The coefficient on arrests will include the effect of prisons.

Table 1. Correlation of Proxy Variables to General Social Survey Responses

Proxies	Definition	*N*	GSSHG	GSSGUN
PGS	Percentage gun suicide	1050	0.576	0.618
AMRMMS	*American Rifleman* circulation	950	0.144	0.181
AMHMS	*American Hunter* circulation	950	0.196	0.331
AMHGS	*American Handgunner* circulation	1100	0.169	0.134
GUNSAMM	*Guns & Ammo* circulation	1150	0.258	0.288
PHG	Imputed HG	1050	0.772	
PGUN	Imputed GUN	1050		0.795

GSSHG is the proportion of households reporting a handgun, GSSGUN is the proportion of households reporting a gun, including handguns, rifles, or shotguns. Magazine circulations are per capita. The reported correlation is the simple correlation across time and states over the entire sample. All variables are measured in their natural units. Definitions and means are given in Table 3.

it is a pistol, rifle, or shotgun. The GSS yields the proportion of households reporting ownership of firearms at the state level.[5] Since handguns are more likely to be used in crime and most handguns are owned for defensive reasons (Kleck 1995, p. 13), we concentrate on the proportion of households reporting ownership of handguns. We replicated our analyses using the percentage of houses reporting ownership of any firearm (not reported to conserve space). The results were the same.

Because the gun question in the GSS survey is not asked in every state in every year, we are missing approximately half the observations on GSS over the period. Therefore, we need a mechanism for estimating the missing data. Our procedure draws on proxy variables that have been used in previous studies: gun magazine subscriptions (Duggan 2001), the proportion of suicides committed with guns, and the proportion of various gun crimes among all crimes (see Kleck 1997, pp. 248–61 for a review). Of these proxies, we discount percentage gun crimes because of the possibility of ratio bias. This leaves percentage gun suicide and gun magazine subscriptions as potential proxies. Percentage gun suicide was taken from the Centers for Disease Control Web site (http://wonder.cdc.gov/). Magazine circulation data were provided by the Audit Bureau of Circulation. Using the proportion of households reporting handgun ownership (GSSHG) as the true measure of handgun availability and the proportion of households reporting any firearm ownership (GSSGUN) as the true measure of ownership of all types of guns, we correlated GSSHG and GSSGUN with percentage gun suicide (PGS) and per capita sales of *American Rifleman, American Hunter, American Handgunner*, and *Guns & Ammo*, the four gun magazines with the largest circulations. The results are reported in Table 1.

Percentage gun suicide is much more closely correlated with the GSS measures than any of the gun magazines. This is also the result found by Azrael, Cook, and Miller (2001). Consequently, we construct a handgun ownership variable by regressing GSSHG on PGS and use the predicted values to impute the missing values of GSSHG. As a robustness check, we also imputed the missing values of GSSGUN using the same methodology. The regressions are reported in Table 2.[6]

This process produces measures (PHG, imputed handguns, and PGUN, imputed guns) whose correlations with the true measures are weighted averages of the perfect correlation between the survey and itself for those 498 observations for which GSS data are available and the correlation

[5] The GSS survey is weighted to reflect national, not state, demographics. However, race and age can vary substantially across states. For example, the proportion of African-Americans is 10.6% for the United States as a whole, but it varies from 0.3% (Vermont) to 35.5% (Mississippi) across states. We use a reweighted version of the GSS, kindly provided by John Whitley, which reflects the individual state's average race and age.

[6] We do not use state dummies in the regression of GSSHG and GSS on PGS. However, we created imputed values of GSSHG and GSS based on regressions with state dummies. The results were unchanged.

Table 2. Regressions of GSSHG and GSSGUN on Percentage Gun Suicide

Dependent Variable	Coefficient	*t* Ratio	R^2	*N*
GSSHG				
Intercept	−15.617	5.73	0.33	488
PGS	0.679	15.49		
GSSGUN				
Intercept	−7.145	2.21	0.38	486
PGS	0.896	17.28		

Variables are measured in their natural units.

between percentage gun suicide and the survey results for the remaining 573 observations. These correlation coefficients are reported in the last two rows of Table 1.

Having both the true value of gun prevalence (GSSHG) and the imputed measure (PHG) allows us to estimate each of the relevant equations using the actual GSSHG data, then reestimate the same equations using the imputed values. The advantage of this process is that we can get an estimate of the order of magnitude of the coefficient using the relatively small number of observations on GSSHG ($n = 498$). We can then verify these estimates, with presumably greater accuracy, using the larger number of observations on the imputed values, PHG ($n = 1071$). If the numerical values of the coefficients are similar between the two equations, we can be more confident that we have good estimates than if we had estimated either equation in isolation.

With a gun measure that is closely related to the GSS, we can identify the crime equation in part by using gun magazine sales as instruments for gun availability on the assumption that gun magazine sales will be related to guns but generally independent of crime. Some individuals might purchase gun magazines if they are considering acquiring a gun in response to an increase in the crime rate. However, we suspect that this group constitutes a small proportion of gun magazine sales, and we test this hypothesis when we estimate the simultaneous equation models below. We can also identify the gun equation through the use of prison and arrests as instruments, which are highly correlated with crime but independent of gun ownership. We make no attempt to estimate the prison or the arrest equation.

In addition, we include the usual control variables (e.g., the proportion of the population in various age groups, unemployment, income, etc.), which comprise the vector of exogenous variables in each equation. The variable names, descriptions, and means are presented in Table 3.

4. Econometric Method

Because we are pooling time series and cross-section data, we have to determine the level of integration of the panels. Im, Pesaran, and Shin (1997) suggest estimating the following augmented Dickey-Fuller test equation for each state:

$$\Delta y_{it} = \alpha_i + (\rho_i - 1)y_{i,t-1} + \sum_{j=1}^{p} \Delta y_{i,t-j} + \varepsilon_{it}.$$

The test for a unit root consists of testing the coefficient on the lagged level with a t-test. To test the null of a unit root across all states, we take the average of the t ratios ("t bar test"). When the errors are serially uncorrelated and independently and normally distributed across states, the resulting test statistic is distributed as standard normal for large N (number of states) and finite T (number of time periods). When the errors are serially correlated and heterogeneous across states, the test statistics are

Table 3. Variable Names, Definitions, and Means

Variable	Label	Mean
HG	GSS handgun prevalence (%)	25.922
PHG	Imputed handgun prevalence (%)	25.481
GUN	GSS gun prevalence (%)	48.588
PGUN	Imputed guns (%)	47.351
PGS	Percentage gun suicide	60.491
GUNSAMM	*Guns & Ammo* circulation	2429.830
AMHGS	*American Handgunner* circulation	597.240
AMHMS	*American Hunter* circulation	6572.120
AMRMMS	*American Rifleman* circulation	6659.130
CRMAJ	Major crime per million population	15,936.020
CRMUR	Murder per million population	68.359
CRRAP	Rape per million population	354.064
CRROB	Robbery per million population	1452.410
CRASS	Assault per million population	2923.820
CRBUR	Burglary per million population	11,137.360
PRISON	Prison population per capita	2272.840
AOMAJ	Arrest rate, major crime	20.202
AOMUR	Arrest rate, murder	87.344
AORAP	Arrest rate, rape	36.591
AOROB	Arrest rate, robbery	29.408
AOASS	Arrest rate, assault	43.196
AOBUR	Arrest rate, burglary	12.984
METPCT	Percentage urban	63.795
AMPCT	Percentage African-American	9.570
MILITARY	Military employment	5.089
EMPLOY	Total employment	27.080
UNRATE	Unemployment rate	6.192
RPCPI	Real per capita personal income	13.184
RPCIM	Real per capita income maintenance	0.170
RPCUI	Real p.c. unemployment insurance	0.067
RPCRPO	Real p.c. retirement payments	0.483
P1517	Percentage population 15–17	4.649
P1824	Percentage population 18–24	11.218
P2534	Percentage population 25–34	16.152
P3544	Percentage population 35–44	14.247
P4554	Percentage population 45–54	10.567
P5564	Percentage population 55–64	8.684
POP	Population	5012.130

valid as T and N go to infinity, as long as N/T goes to some finite positive constant. The tests are consistent under the alternative hypothesis that the fraction of the individual processes that are stationary is nonzero. We apply this test to all the variables in the model allowing the number of lags to vary from zero to three with, and without, a linear trend term.

The tests indicate that guns, crime, and prison are nonstationary $I(1)$ variables. Arrests appear to be stationary. Of the control variables, only the percentage urban and percentage African-American are definitely stationary. The remaining variables are almost certainly $I(1)$ except for the proportion of the population between 35 and 44 where the results depend on whether one includes a trend, and the unemployment rate, which depends crucially on the number of lags. Overall, the variables appear to be nonstationary random walks.

Table 4. Long-Run Models[a]

	Major Crime				Murder				Rape			
	GSSHG		PHG		GSSHG		PHG		GSSHG		PHG	
Variable	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio
Guns	0.00019	0.48	0.00005	0.15	−0.00014	0.23	−0.00033	0.56	0.00078	1.55	**0.00078**	**1.73**
Prison	**−0.07993**	**6.48**	**−0.07778**	**9.71**	**−0.12239**	**6.26**	**−0.11970**	**8.80**	**−0.07248**	**4.57**	**−0.05911**	**5.64**
Arrests	**−0.00244**	**2.78**	**−0.00275**	**4.23**	**−0.00069**	**2.66**	**−0.00046**	**2.88**	−0.00097	1.51	**−0.00098**	**2.30**
METPCT	−0.00205	0.29	0.00645	1.96	−0.00678	0.60	0.00202	0.36	−0.01085	1.18	0.00382	0.89
AMPCT	**−0.06784**	**5.88**	**−0.06484**	**8.28**	**0.07147**	**3.91**	**0.06160**	**4.63**	**−0.06649**	**4.44**	**−0.07091**	**6.91**
EMPLOY	**−0.03532**	**3.64**	**−0.02884**	**4.09**	0.02196	1.46	0.00101	0.09	**−0.07749**	**6.18**	**−0.09746**	**10.58**
UNRATE	0.00013	0.02	−0.00082	0.22	**−0.02626**	**3.91**	**−0.03392**	**5.53**	**−0.01692**	**2.49**	**−0.01213**	**2.54**
P1517	**13.16622**	**3.60**	**3.85463**	**1.80**	0.41840	0.07	−4.78869	1.32	5.03504	1.07	**7.11067**	**2.55**
P1824	1.04390	0.66	**1.89184**	**2.05**	−0.38562	0.16	1.60937	1.04	−1.80779	0.90	1.42613	1.19
P2534	**13.10214**	**8.97**	**10.32273**	**11.93**	**5.15925**	**2.24**	**5.77788**	**3.96**	0.94669	0.50	**4.02570**	**3.56**
P3544	−0.37994	0.24	**−2.48008**	**2.40**	2.87686	1.14	0.57067	0.33	**11.34025**	**5.55**	**12.06604**	**8.94**
P4554	**−4.86070**	**2.15**	**−4.50682**	**3.15**	−0.22909	0.06	−0.63158	0.26	**−12.31786**	**4.23**	**−9.37906**	**5.00**
P5564	**11.52524**	**5.28**	**11.39638**	**8.12**	5.24728	1.51	0.64319	0.27	**19.96232**	**7.10**	**14.34768**	**7.82**
RPCPI	**−0.04204**	**3.47**	**−0.04781**	**6.26**	−0.01173	0.61	**−0.04121**	**3.17**	**0.02571**	**1.65**	0.00817	0.82
RPCIM	0.05278	0.22	0.01164	0.07	0.17799	0.46	0.02433	0.08	−0.22450	0.72	**−0.44973**	**2.02**
RPCUI	0.26027	1.08	0.17891	1.09	0.02020	0.05	0.22678	0.84	−0.22022	0.71	**−0.38067**	**1.77**
RPCRPO	−0.07090	1.43	**−0.05066**	**1.78**	**−0.28817**	**3.66**	**−0.33674**	**6.99**	−0.01854	0.29	−0.01015	0.27
Intercept	**8.81553**	**11.09**	**9.31631**	**19.81**	**2.51757**	**2.02**	**3.22840**	**4.11**	**6.09541**	**6.06**	**4.55357**	**7.53**

Dependent variables are measured in logs, data are annual from 1977 to 1998. All regressions also include state and year dummy variables. Regressions weighted by population. Coefficients in columns 1 and 5 are estimated using the actual GSS handgun measure (GSSHG). Coefficients in columns 3 and 7 are estimated using imputed handguns (PHG). The number of observations is 464 for regressions using GSS and 953 for regressions using imputed guns. Coeff, coefficient.
[a] Bold coefficients are significant at the 10% level (two-tailed).

According to Phillips and Moon (1999), pooled time series and cross-section panel models are ideal for estimating the long-run average relationships among $I(1)$ variables in levels. The pooled panel estimator yields consistent estimates with a normal limit distribution. These results hold in the presence of individual fixed effects (Phillips and Moon 1999, pp. 1088–91). The coefficients are analogous to the population (not sample) regression coefficients in conventional regressions.

The problem with estimating a long-run static regression model is that the direction of causation cannot be easily determined. Thus, a positive relationship between guns and crime could reflect that guns cause crime or that crime causes guns. However, a negative long-run relationship between guns and crime would be indicative of crime reduction by guns in the long run.

Determining the direction of causation is somewhat easier in the short-run first difference regression. In a time series or panel of time series, lags can be used to identify causal relationships. If the lags are long enough, their existence could even eliminate the need for simultaneous equation modeling. In the following section, we estimate both long-run static and short-run dynamic panel data models of guns and crime.

All regressions are weighted by population in order to reduce the influence of small states, which are underrepresented in the GSS survey and have more erratic crime trends.

5. Results[7]

The long-run static results are presented in Table 4. We include arrests as an explanatory variable because the direction of causation is difficult to determine in the long-run static model in any case, and

[7] Data and programs used to generate the tables reported in this section, plus programs generating unreported results, are available at http://cemood.people.wm.edu/research.html. Click on the link "Programs and Data for Guns and Crime."

Table 4. Extended

Robbery				Assault				Burglary			
GSSHG		PHG		GSSHG		PHG		GSSHG		PHG	
Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio
0.00007	0.11	−0.00005	0.08	−0.00001	0.01	0.00013	0.26	0.00018	0.43	0.00000	0.01
−0.12785	**6.32**	**−0.12775**	**9.34**	−0.02153	1.31	**−0.02908**	**2.50**	**−0.09891**	**7.28**	**−0.09195**	**10.45**
−0.00038	0.88	−0.00062	1.63	**−0.00094**	**1.86**	**−0.00199**	**5.28**	**−0.00914**	**4.34**	**−0.00575**	**4.10**
0.03157	**2.69**	**0.01547**	**2.76**	0.00738	0.77	0.00223	0.47	−0.00001	0.00	**0.00816**	**2.27**
−0.08330	**4.36**	**−0.08425**	**6.30**	**−0.03488**	**2.28**	**−0.03564**	**3.14**	**−0.07890**	**6.20**	**−0.08133**	**9.46**
0.01195	0.77	0.00969	0.82	0.01696	1.33	**0.03092**	**3.06**	**−0.05160**	**4.76**	**−0.05185**	**6.64**
0.00839	0.98	−0.00244	0.40	**−0.01447**	**2.09**	**−0.00906**	**1.72**	0.00154	0.27	0.00044	0.11
13.38347	**2.24**	−1.62086	0.45	−3.26775	0.67	0.31076	0.10	**15.91996**	**3.97**	**5.55330**	**2.37**
2.74952	1.07	**5.47112**	**3.51**	**6.69634**	**3.21**	**2.59420**	**1.95**	−1.09811	0.64	1.05279	1.04
14.34496	**6.07**	**13.58148**	**9.29**	**6.11655**	**3.17**	**5.18275**	**4.16**	**12.65495**	**7.89**	**10.40270**	**10.97**
2.48301	0.95	−0.51036	0.29	**4.00709**	**1.90**	2.16343	1.44	−1.36918	0.78	**−3.01415**	**2.66**
−10.61787	**2.88**	**−7.70906**	**3.17**	−4.47110	1.49	**−7.87229**	**3.80**	**−5.31759**	**2.15**	**−3.77590**	**2.42**
16.95328	**4.74**	**17.46334**	**7.31**	**7.55551**	**2.61**	**10.02619**	**4.93**	**13.34774**	**5.56**	**12.91734**	**8.41**
0.00331	0.17	**−0.02432**	**1.86**	**−0.02904**	**1.81**	−0.00620	0.56	**−0.04440**	**3.32**	**−0.05650**	**6.73**
−0.67761	**1.71**	−0.16346	0.57	**0.59022**	**1.84**	0.27171	1.10	0.00308	0.01	−0.01560	0.08
−0.45967	1.19	−0.05838	0.21	0.48428	1.55	0.14678	0.63	**0.53048**	**2.05**	**0.39974**	**2.28**
−0.13098	1.61	**−0.17035**	**3.52**	−0.02873	0.44	−0.03183	0.77	−0.06457	1.19	−0.02930	0.94
3.29471	**2.56**	**5.24079**	**6.63**	**6.39846**	**6.05**	**7.41994**	**10.89**	**8.94598**	**10.41**	**9.28541**	**18.23**

we want to avoid omitted variable bias, if possible. We also estimated the model excluding the arrest variable. The results are the same. The regressions are estimated in semi-log form with the dependent variable measured in logarithms, although the results are the same if all variables are logged. We use a fixed effects model with state dummy variables to control for unobserved heterogeneity across states and year dummy variables to control for common trends in crime rates.

The coefficients on guns in all the crime equations are numerically very small, and most are insignificantly different from zero. The coefficients on guns in those equations using the imputed gun values (PHG) are very close to those estimated using the actual GSS values (GSSHG). Thus, the net effect of guns on crime in the long run is approximately zero. With respect to the individual crime categories, we find that handguns appear to have a very small but positive effect on rape. However, since only 4% of rapes are committed by rapists armed with guns (Kleck 1997, p. 240), the positive long-run relationship between guns and rape may be due to reverse causation.

With respect to sanctions, prison incarceration is negative and significant in all crime equations, except for the assault equation using the GSS handgun variable. Arrests have a negative and generally significant effect on all crimes, except robbery.[8]

We now transform to stationary, $I(0)$, variables by taking first differences. This allows us to model the short-run fixed effects model of crime and guns using standard testing procedures.[9]

In Table 5 we show the result of a series of Granger causality tests (Granger 1969) relating guns to crime.

The estimated coefficients on the lagged handgun variables are numerically small and insignificant, apart from a small negative effect on assault, indicating that handguns have virtually no effect on crime. With the exception of the assault equation, prison is significant and negative in all the

[8] Executions were never significant in any of our murder equations.

[9] Taking first differences of nonstationary $I(1)$ variables transforms them to stationary $I(0)$ variables so that all the usual tests are relevant. First differences of $I(0)$ variables remain stationary.

Table 5. Granger Causality Tests: Do Guns Cause Crime?[a]

	Major Crime				Murder				Rape			
	GSSHG		PHG		GSSHG		PHG		GSSHG		PHG	
Variable	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio
GUNS (−1)	0.00026	0.77	−0.00003	0.14	0.00010	0.13	0.00020	0.41	−0.00049	1.05	−0.00020	0.67
GUNS (−2)	0.00022	0.64	−0.00006	0.29	0.00029	0.38	−0.00010	0.20	−0.00035	0.74	0.00009	0.31
CRIME (−1)	0.09736	0.97	**0.24359**	**6.35**	**−0.25148**	**2.83**	**−0.33126**	**8.95**	**−0.28318**	**2.93**	−0.05183	1.38
CRIME (−2)	−0.06484	0.57	**−0.14371**	**3.96**	0.10901	1.16	−0.05470	1.46	−0.01178	0.11	−0.04300	1.12
PRISON	**−0.14784**	**3.14**	**−0.05824**	**3.53**	**−0.32857**	**3.10**	−0.05155	1.27	−0.05871	0.92	**−0.04848**	**1.99**
ARRESTS	0.00003	0.02	**−0.00111**	**2.24**	**−0.00137**	**2.39**	**−0.00040**	**2.92**	**−0.00303**	**3.23**	**−0.00096**	**2.87**
METPCT	−0.01286	0.33	**0.03992**	**3.24**	−0.04306	0.48	**0.06001**	**1.98**	−0.05806	1.06	**0.03918**	**2.15**
AMPCT	−0.02521	0.36	**−0.08571**	**2.90**	−0.05154	0.33	−0.06049	0.85	0.05558	0.57	−0.06024	1.39
EMPLOY	−0.03210	0.65	**−0.03661**	**2.11**	0.18037	1.64	**−0.11046**	**2.60**	0.00152	0.02	**−0.06879**	**2.67**
UNRATE	**0.01525**	**1.70**	0.00084	0.27	−0.00676	0.33	−0.00913	1.22	0.01268	1.07	**−0.01327**	**2.95**
P1517	−9.90833	0.99	**12.44695**	**5.12**	−5.23198	0.24	**14.88732**	**2.70**	0.50566	0.04	3.94612	1.16
P1824	−2.08217	0.41	1.04098	0.59	**−18.96434**	**1.67**	4.79111	1.11	4.99088	0.70	1.12622	0.43
P2534	3.32395	0.74	**4.47633**	**3.19**	2.36388	0.25	2.59449	0.77	−8.14712	1.40	−0.84118	0.41
P3544	−4.05266	0.76	2.06097	1.10	−4.07950	0.34	**18.00558**	**3.86**	7.29729	1.00	**7.85004**	**2.71**
P4554	**−17.56738**	**3.62**	1.79182	0.99	**−31.37882**	**2.88**	**9.63681**	**2.19**	−8.58118	1.24	−1.85384	0.70
P5564	**20.07909**	**2.12**	**−16.79905**	**5.91**	**50.17335**	**2.37**	**−50.27952**	**7.30**	15.90735	1.21	**−8.58979**	**2.08**
RPCPI	0.03235	0.84	**−0.01608**	**1.85**	0.09868	1.13	−0.00644	0.30	0.07952	1.50	0.01655	1.30
RPCIM	−0.08227	0.13	−0.06810	0.47	−1.25138	0.96	0.54054	1.51	−0.14763	0.17	0.16351	0.76
RPCUI	−0.17787	0.42	−0.02628	0.21	−0.59995	0.63	0.23435	0.76	−0.45976	0.78	0.14189	0.77
RPCRPO	−0.72771	0.40	**−0.00972**	**1.82**	2.88212	0.74	−0.01840	1.39	**−7.42005**	**2.98**	**−0.03243**	**4.07**
Intercept	**0.10819**	**2.34**	−0.01230	1.15	**0.23490**	**2.31**	**−0.10601**	**3.97**	**0.11736**	**1.85**	−0.01524	0.96

All variables measured as first differences; dependent variables measured as first differences of logs; (−1) indicates one-period lag, etc.; crime is the dependent variable defined as major crime, murder, rape, robbery, assault, and burglary. The definition of guns (GSSHG or PHG) is also given at the top of the table. Regressions weighted by population. State and year dummy variables were not significant. Results are unchanged if all variables are measured as first differences of logs.

[a] Bold coefficients are significant at the 10% level (two-tailed).

crime equations that are estimated with the larger number of observations associated with the imputed handgun variable. The arrest rate is negative and significant in all the crime equations estimated with the larger data set.

These results differ from those of Duggan (2001), who reports regressions of the first differences of the log of murders on the lagged first differences of the log of guns, measured as the circulation of *Guns & Ammo* magazine. We attribute the difference between Duggan's results and ours to two things. First, we use two measures of gun availability, both of which are better measures of gun availability than *Guns & Ammo* circulation. As Table 1 shows, the percentage gun suicide is much more highly correlated with GSS survey data than *Guns & Ammo* sales. Our gun variable, which uses actual GSS data where it is available, is even more highly correlated with the GSS data than percentage gun suicide. Second, Duggan did not use the age categories that are commonly employed as control variables in most crime studies. His single control variable for the age distribution is the percentage of the population between 18 and 24. Most researchers typically use more age groups. This is important in Duggan's case because there is considerable demographic similarity between criminals and gun magazine readership, with high levels in several age groups above the 18–24 age group, implying possibly serious omitted variable bias.

In Table 6 we test whether crime Granger-causes handguns. The state dummies, control variables, and the second lags of the crime variables were not significant.

Table 5. Extended

Robbery				Assault				Burglary			
GSSHG		PHG		GSSHG		PHG		GSSHG		PHG	
Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio
−0.00016	0.28	−0.00005	0.15	−0.00004	0.09	−0.00020	0.70	0.00021	0.54	−0.00003	0.11
−0.00056	0.98	−0.00016	0.45	0.00004	0.08	**−0.00048**	**1.70**	0.00025	0.65	0.00017	0.75
0.10494	1.13	**0.09905**	**2.53**	−0.04250	0.40	**0.09587**	**2.69**	0.05751	0.60	0.02326	0.62
−0.03368	0.37	**−0.08902**	**2.47**	0.05901	0.59	0.02562	0.70	−0.10499	0.94	**−0.07709**	**2.09**
−0.25302	**3.16**	**−0.09698**	**3.41**	−0.01440	0.22	0.00906	0.39	**−0.19844**	**3.67**	**−0.07906**	**3.37**
−0.00134	1.05	**−0.00171**	**3.29**	−0.00029	0.36	**−0.00070**	**2.46**	−0.00271	1.22	**−0.00252**	**3.11**
−0.04356	0.65	**0.06832**	**3.21**	−0.01874	0.34	**0.03293**	**1.87**	0.00219	0.05	0.01429	**1.71**
−0.03273	0.27	**−0.15192**	**2.99**	−0.06000	0.62	**−0.07561**	**1.82**	−0.03654	0.47	−0.10314	**2.21**
0.12992	1.56	−0.04840	1.59	−0.06680	0.99	−0.01377	0.56	−0.04518	0.82	−0.05634	1.63
0.00914	0.61	0.00011	0.02	−0.00558	0.46	−0.00480	1.10	**0.02370**	**2.41**	0.00318	0.90
−22.68829	1.37	**10.12272**	**2.58**	**−35.45988**	**2.68**	**7.27572**	**2.26**	−1.29579	0.12	**17.24482**	**6.38**
−7.19301	0.83	4.66854	1.53	7.45876	1.04	1.98472	0.79	−3.97755	0.70	1.40035	0.85
−2.85066	0.39	−0.22796	0.10	−7.47899	1.31	1.76151	0.90	6.45090	1.33	**4.98016**	**3.50**
−7.73107	0.86	**8.38623**	**2.57**	−8.56943	1.17	**8.30407**	**3.07**	−2.55567	0.42	−0.25992	0.14
−31.07314	**3.76**	1.47287	0.48	−15.08672	2.15	−3.41558	1.33	−20.37071	3.65	0.87196	0.44
37.77708	**2.37**	**−31.90619**	**6.59**	**18.74873**	1.41	**−18.91296**	**4.73**	**21.35444**	**2.03**	**−9.89988**	**3.25**
0.05781	0.87	−0.00484	0.33	0.06706	1.27	0.04465	**3.62**	**0.03232**	**0.74**	**−0.01700**	**2.01**
−0.32161	0.33	**0.61402**	**2.43**	0.43414	0.54	**0.55222**	**2.64**	−0.32674	0.49	−0.22011	1.02
−0.10938	0.15	0.26168	1.21	−0.42593	0.73	0.25922	1.45	−0.04070	0.09	0.11891	0.75
−0.22914	0.08	−0.00432	0.47	−3.86151	1.62	−0.00556	0.73	−0.05790	0.03	−0.00296	0.40
0.21029	2.72	**−0.03249**	**1.76**	**0.14749**	**2.35**	−0.02437	1.59	**0.09884**	**1.92**	−0.00004	0.00

Although not reported to save space, year dummy variables were highly significant as a group and were retained. There is some evidence from the equations using GSSHG that major crime in general, and burglary in particular, may cause people to acquire handguns. However, these results are not confirmed by the larger data set using imputed handguns, where none of the lags of the crime variable are significantly different from zero. Thus, we cannot say with confidence that crime Granger-causes guns. The major cause of guns appears to be lagged guns, the negative coefficients indicating significant reversion to the mean.

Granger causality is neither necessary nor sufficient for simultaneous equation bias. Even if independent in a Granger causality sense, there could be contemporaneous causality running in either direction between guns and crime. In Table 7 we report estimates of the short-run crime equation based on first differences. We apply the Hausman-Wu test (Wu 1973; Hausman 1978) to determine whether there is significant simultaneous equation bias present in the crime equation. The coefficients are very small and insignificantly different from zero, indicating no simultaneous equation bias. This is consistent with the Granger causality analysis reported in Table 6 and implies that we are justified in employing ordinary least squares (OLS) to estimate the crime equation. However, for completeness, we estimate both two-stage least squares and OLS versions of all equations.

We make the realistic assumption that there is a significant lag between the commission of a crime and the eventual incarceration of the criminal. Consequently, we assume that prison population is predetermined in the crime equation.

We find numerically small, but significantly positive, coefficients on handguns for GSSHG in the OLS versions of the major crime and rape equations, but these coefficients are not verified by the larger sample PHG versions of the same equations where the corresponding coefficients are insignificant. The only significant coefficient using the larger sample is in the assault equation. However, the coefficient is of the opposite sign from that of the GSSHG version of the equation. The numerical values are again very small, even when significantly different from zero. So, for example, using the coefficient on GSSHG in the OLS version of the major crime equation, a doubling of the number of households reporting handgun ownership from 26% to 52% would cause major crime to increase by only 1%, implying an elasticity of crime with respect to handguns of 0.02.

There is some evidence that handguns cause burglary. This finding agrees, in part, with those of Cook and Ludwig (2003, pp. 88–93), who find a positive and significant coefficient on percentage gun suicide in their burglary equation, implying an elasticity of burglary with respect to guns of 0.67 (p. 89). However, they estimate the panel data model using three-year averages rather than yearly data. This will have the effect of artificially reducing the variance and inflating the t ratios. In fact, Cook and Ludwig report (p. 88, fn. 40) that the results using annual data do, in fact, yield higher standard errors. Also, their point estimates are not comparable to ours because they use a proxy, percentage gun suicide, rather than actual GSS values or imputed GSS values. Consequently, their coefficient estimates cannot be used to predict the percentage change in burglary from a given percentage change in guns. See Moody and Marvell (2003). Our estimate of the elasticity of burglary with respect to handguns is 0.01, which is not significant in the larger sample using imputed handgun values.

Prison has a significantly negative effect on all categories of crime except assault. The coefficients on the arrest rate are negative and significant for all crime categories. The Basmann (1969) test for overidentification is significant in the major crime and burglary equations, indicating that these models may not be properly identified. However, the Hausman-Wu tests indicate that the OLS models are consistent and therefore are preferred to the two-stage least squares models.

In Table 8 we report the results of our estimates of the short-run handgun equation. For the equations using GSSHG, the Hausman-Wu tests indicate that two-stage least squares is the preferred estimation technique. These equations indicate that major crime in general and assault and burglary in particular cause handguns, confirming the Granger causality tests previously reported. The estimated coefficients on crime in the handgun equations are larger than the corresponding coefficients relating guns to crime. For example, using the estimated coefficient on major crime from column 1 in Table 8, a 1% increase in major crime will cause the proportion of households with handguns to increase by 0.44% (to 26.44%), an implied elasticity of 1.76. The coefficient on burglary in the GSS handgun equation implies an elasticity of handguns with respect to burglary of 1.46. This contrasts with Cook and Ludwig's (2003) elasticity estimate of 0.06–0.07 (p. 91). However, the coefficients and significance levels are not consistent between the GSS measure and the imputed values, so we cannot conclude with confidence that crime causes handguns.

6. Are the Results Due to Attenuation Bias Caused by Errors in Variables?[10]

The fact that the estimated coefficients on guns in the crime equation are very small might be due to errors in variables. Measurement error in the imputed handgun variable could cause the coefficient estimates to be biased toward zero. However, if this were the case, we would expect that the coefficient estimates for PHG would be much smaller than the coefficient estimates for GSSHG,

[10] This section is the result of a suggestion by an anonymous referee.

Table 6. Granger Causality Tests: Does Crime Cause Guns?[a]

Variable	Dependent Variable: GSSHG Coeff	*t* Ratio	Variable	Dependent Variable: PHG Coeff	*t* Ratio
CRMAJ(−1)	**0.00363**	**1.99**	CRMAJ(−1)	0.00029	0.86
CRMAJ(−2)	−0.00199	1.12	CRMAJ(−2)	−0.00001	0.02
GSSHG(−1)	**−0.57048**	**5.26**	PHG(−)	**−0.63134**	**19.75**
GSSHG(−2)	**−0.21011**	**1.90**	PHG(−2)	**−0.30514**	**9.57**
Intercept	**−5.30938**	**2.66**	Intercept	−0.68577	0.90
CRMUR(−1)	−0.23537	1.48	CRMUR(−1)	−0.03410	1.00
CRMUR(−2)	0.30567	1.58	CRMUR(−2)	0.02722	0.81
GSSHG(−1)	**−0.51752**	**4.92**	PHG1	**−0.62988**	**19.73**
GSSHG(−2)	**−0.24402**	**2.27**	PHG2	**−0.30539**	**9.59**
Intercept	**−4.21194**	**1.80**	Intercept	−0.94279	1.21
CRRAP(−1)	−0.03518	0.52	CRRAP(−1)	0.00231	0.22
CRRAP(−2)	−0.05535	0.78	CRRAP(−2)	−0.00912	0.88
GSSHG(−1)	**−0.55372**	**5.02**	PHG(−)	**−0.62924**	**19.70**
GSSHG(−2)	**−0.20078**	**1.85**	PHG(−2)	**−0.30384**	**9.54**
Intercept	−3.78631	1.40	Intercept	−0.99705	1.40
CRROB(−1)	−0.00037	0.04	CRROB(−1)	−0.00035	0.21
CRROB(−2)	−0.00328	0.37	CRROB(−2)	0.00095	0.60
GSSHG(−1)	**−0.53912**	**4.96**	PHG(−)	**−0.63014**	**19.73**
GSSHG(−2)	**−0.19787**	**1.81**	PHG(−2)	**−0.30547**	**9.58**
Intercept	**−4.48390**	**1.65**	Intercept	−0.81964	1.07
CRASS(−1)	0.00130	0.22	CRASS(−1)	−0.00108	0.90
CRASS(−2)	−0.00455	0.58	CRASS(−2)	0.00021	0.17
GSSHG(−1)	**−0.54536**	**5.01**	PHG(−)	**−0.62917**	**19.69**
GSSHG(−2)	**−0.19487**	**1.78**	PHG(−2)	**−0.30373**	**9.53**
Intercept	−4.83914	1.53	Intercept	−1.09152	1.45
CRBUR(−1)	**0.00455**	**2.21**	CRBUR(−1)	0.00455	1.51
CRBUR(−2)	−0.00259	1.11	CRBUR(−2)	−0.00259	0.36
GSSHG(−1)	**−0.57667**	**5.27**	PHG(−)	**−0.63227**	**19.78**
GSSHG(−2)	**−0.21462**	**1.94**	PHG(−2)	**−0.30449**	**9.54**
Intercept	−3.22107	1.40	Intercept	−0.69802	0.96

All variables measured as first differences (not logged); (−1) indicates one-period lag, etc.; all regressions include first differences of year dummy variables (not reported). Regressions weighted by population. State dummy variables, control variables, and crime lags greater than one were not significant. Results are unchanged if all variables are measured as first differences of logs.

[a] Bold coefficients are significant at the 10% level (two-tailed).

which uses the actual GSS data. Since the estimates using the actual variable are extremely close to those using the imputed values, we are confident that the numerically small coefficient estimates on PHG are not caused by measurement error.

However, the presumption that the GSS survey is the true measure of gun ownership may not be correct. Only 3000 individuals are interviewed for the GSS in each year, and some states are not sampled in certain years. Also, there is some evidence (Azrael, Cook, and Miller 2001) that rates of gun ownership are quite stable. This could mean that the year-to-year variation is caused primarily by random variation in the GSS rather than actual changes in gun ownership. If true, then the small estimated coefficients in the crime equations could be caused by attenuation bias due to classical errors in variables.

We can estimate the potential attenuation bias by estimating the signal-to-noise ratio as follows. Suppose the true rate of gun ownership is constant across time for each state. Then the variance of the

Table 7. Short-Run Crime Equations[a]

	Major Crime				Murder				Rape			
	2SLS		OLS		2SLS		OLS		2SLS		OLS	
	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio
GSSHG	0.00032	0.76	**0.00043**	**2.03**	−0.00013	0.15	0.00076	0.90	0.00039	0.67	**0.00080**	**2.27**
PHG	0.00024	1.00	0.00016	0.98	0.00047	0.68	0.00000	0.00	0.00063	1.59	0.00038	1.28
PRISON	**−0.09771**	**6.72**	**−0.12626**	**6.59**	**−0.13689**	**3.35**	**−0.12042**	**1.66**	−0.03480	1.50	**−0.08220**	**2.38**
AOMAJ	**−0.00114**	**2.45**	**−0.00099**	**2.24**	**−0.00035**	**2.70**	**−0.00032**	**3.07**	**−0.00200**	**5.48**	**−0.00189**	**5.32**
CRMAJ1	**0.07993**	**2.09**	−0.01868	0.55	**−0.36650**	**10.21**	**−0.46486**	**15.19**	**−0.19030**	**5.03**	**−0.23283**	**7.26**
METPCT	0.01498	1.35	0.00205	0.31	0.01780	0.56	0.00963	0.38	0.01857	1.03	0.01138	0.95
AMPCT	**−0.07338**	**2.59**	−0.03277	0.92	−0.05184	0.65	0.11307	0.84	**−0.11955**	**2.62**	−0.07788	1.21
DPOP	−0.00001	1.15	−0.00002	0.68	−0.00002	0.49	0.00000	0.04	**−0.00009**	**4.35**	**−0.00011**	**2.71**
RPCPI	**−0.01764**	**2.29**	**−0.01652**	**2.49**	−0.00219	0.10	0.00445	0.18	0.00557	0.45	0.00594	0.50
RPCIM	0.15969	0.95	0.47364	2.24	−0.56049	1.17	−1.14245	1.43	−0.33117	1.22	−0.18880	0.50
RPCUI	**0.22946**	**1.88**	**0.34972**	**3.45**	0.08541	0.24	0.62992	1.64	−0.21748	1.10	−0.27947	1.53
RPCRPO	**−0.06390**	**2.98**	−0.05248	1.61	**−0.15496**	**2.54**	−0.13152	1.06	−0.01371	0.40	−0.02246	0.38
P1517	**10.22606**	**2.32**	**11.91429**	**3.49**	−7.58419	0.61	0.63568	0.05	2.06500	0.29	**14.50195**	**2.35**
P1824	1.95611	1.22	**3.12441**	**2.53**	5.10643	1.12	6.02145	1.30	3.63942	1.41	2.77470	1.26
P2534	**7.78001**	**4.78**	**7.27523**	**6.36**	**7.74465**	**1.71**	**10.60762**	**2.50**	−2.84434	1.10	2.79609	1.38
P3544	**−4.92209**	**2.20**	**−12.09381**	**7.52**	−7.31304	1.15	**−9.91490**	**1.65**	1.23237	0.34	**−7.20810**	**2.52**
P4554	−3.07608	0.95	**−6.58438**	**2.53**	−1.37932	0.15	−3.84171	0.39	−6.38170	1.21	**−11.33280**	**2.41**
P5564	2.42122	0.65	10.10348	3.18	−2.63711	0.25	3.76093	0.31	6.90828	1.15	7.50310	1.32
RPCPI1	0.00576	0.66	**0.02837**	**3.78**	0.02188	0.88	−0.01343	0.47	**0.02900**	**2.05**	**0.05916**	**4.39**
RPCIM1	−0.02068	0.11	**0.38080**	**1.77**	0.30665	0.59	1.20524	1.49	0.36612	1.23	0.54183	1.41
RPCUI1	**0.45098**	**3.91**	0.09126	0.90	−0.00820	0.02	−0.24915	0.65	−0.24986	1.33	−0.25814	1.41
RPCRPO1	**−0.04548**	**1.93**	−0.03178	0.93	−0.10927	1.62	−0.19229	1.48	0.00246	0.06	0.04787	0.78
Intercept	0.01500	0.99	**0.03976**	**3.68**	−0.04095	0.95	−0.02578	0.63	**0.06326**	**2.59**	**0.08680**	**4.43**
H-W	0.00028	0.87			0.00046	0.52			0.00025	0.51		
Overid		**1.73**				1.06				1.18		

All variables measured as first differences; dependent variables are first differences of logs; (−1) indicates one-period lag. The coefficients on gsshg are from the crime equations using actual GSS data; the remaining coefficients are from equations using imputed handguns with more observations; dpop is the change in population. Each equation also includes first differences of year dummies (not reported). State dummy variables were not significant. Regressions weighted by population. 2SLS indicates two-stage least squares estimation. The list of instruments consists of percentage urban, percentage African-American, population, six age groups, four income categories, lagged crime, four lagged income categories, circulation of the four gun magazines, total employment, the unemployment rate, all of the above variables lagged twice, and crime, prisons, and handguns lagged twice. Overid is the Basmann *F* test for overidentifying restrictions; a significant value indicates that the two-stage least squares model may not be correctly identified. H-W is the coefficient on the predicted value of handguns in the Hausman-Wu test for specification error; a significant value implies that OLS is not consistent. Results are unchanged if the arrest rate is omitted. Results are unchanged if all variables are measured as first differences of logs.

[a] Bold coefficients are significant at the 10% level (two-tailed).

true, but unobserved, variable is the variance of the state means, calculated over all years, σ_x^2. The variance of the measurement error term, σ_v^2, is thus the remaining variance over time, the difference between the total variance across time and states and the variance of the state means. If the measurement error is classical, the probability limit of the estimate of the coefficient is given by

$$P\lim b = \beta/(1 + \sigma_v^2/\sigma_x^2),$$

where b is the estimated coefficient and β is the true coefficient on guns in the crime equation.

In our sample, the variance of the mean is $\sigma_x^2 = 112.56$, while the estimated variance of the error term is $\sigma_v^2 = 118.19$. Therefore, under these assumptions, the estimated coefficient is approximately one-half the true value. The basic conclusions are unchanged, even with this amount of attenuation bias. For example, the estimated coefficient on GSSHG in the Major Crime equation in Table 7, column 3, is 0.00043. If this is underestimated by one-half, the true coefficient is 0.00086. This means that a doubling of the proportion of households reporting handgun ownership from 26% to 52% will

Table 7. Extended

Robbery				Assault				Burglary			
2SLS		OLS		2SLS		OLS		2SLS		OLS	
Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio	Coeff	*t* Ratio
0.00007	0.09	0.00057	1.51	−0.00028	0.49	0.00048	1.53	0.00065	1.34	**0.00040**	**1.67**
0.00013	0.30	0.00026	0.86	**0.00085**	**2.21**	0.00036	1.33	0.00010	0.37	0.00013	0.74
−0.16242	**6.48**	**−0.18934**	**5.30**	−0.02717	1.21	−0.00622	0.20	**−0.11586**	**7.15**	**−0.15666**	**7.47**
−0.00148	**3.32**	**−0.00102**	**3.48**	**−0.00103**	**3.52**	**−0.00155**	**5.51**	**−0.00301**	**3.01**	**−0.00188**	**2.46**
0.06817	**1.78**	**−0.05994**	**1.80**	**0.10792**	**2.76**	0.04595	1.37	**0.06694**	**1.77**	−0.05120	1.53
0.03391	**1.76**	−0.01075	0.86	0.01497	0.85	−0.00362	0.33	0.01528	1.23	0.00490	0.67
−0.13477	**2.79**	−0.00853	0.13	−0.04499	1.03	0.02365	0.40	**−0.08503**	**2.73**	−0.06025	1.55
−0.00001	0.26	0.00003	0.73	0.00002	1.08	0.00002	0.59	**−0.00003**	**2.31**	−0.00003	1.38
−0.00749	0.56	0.00656	0.53	**0.02006**	**1.66**	**0.03552**	**3.29**	**−0.03079**	**3.59**	**−0.03030**	**4.16**
0.23555	0.81	0.12009	0.31	0.35258	1.33	0.11428	0.33	0.13714	0.73	**0.47262**	**2.05**
0.27870	1.32	**0.49149**	**2.60**	−0.08515	0.44	−0.03822	0.23	**0.34779**	**2.55**	**0.44989**	**4.06**
−0.08499	**2.29**	**−0.10240**	**1.68**	**−0.06009**	**1.78**	−0.02844	0.53	**−0.05625**	**2.36**	**−0.05929**	**1.66**
11.05917	1.48	**13.81151**	**2.17**	−3.38848	0.50	**10.03734**	**1.79**	**12.92546**	**2.67**	**12.45879**	**3.35**
2.65318	0.96	**7.47190**	**3.25**	3.89903	1.54	1.33655	0.67	1.67613	0.94	**3.23176**	**2.41**
4.95654	**1.80**	**10.26249**	**4.83**	2.68774	1.08	2.17564	1.17	**8.86043**	**4.96**	**8.08623**	**6.50**
−11.41080	**2.96**	**−10.66940**	**3.60**	0.00666	0.00	−3.24613	1.24	**−5.46918**	**2.19**	**−13.74757**	**7.83**
−8.23827	1.48	**−15.14480**	**3.11**	−2.07513	0.41	−4.72012	1.10	−4.25295	1.18	**−6.95743**	**2.45**
3.86824	0.60	**18.40750**	**3.11**	2.92470	0.50	**9.30513**	**1.78**	3.30803	0.80	**9.84490**	**2.85**
0.04148	**2.75**	0.02244	1.61	0.01886	1.37	**0.03761**	**3.03**	−0.00115	0.12	**0.02452**	**2.97**
−0.34179	1.08	0.39532	0.99	0.17649	0.61	0.29259	0.83	−0.01821	0.09	**0.39981**	**1.70**
0.31730	1.59	0.28863	1.52	−0.02293	0.13	**−0.34990**	**2.09**	**0.58041**	**4.50**	**0.20345**	**1.83**
−0.02171	0.53	−0.05145	0.80	−0.02551	0.69	0.00412	0.07	**−0.05188**	**1.98**	−0.04839	1.30
0.02916	1.12	**0.03361**	**1.67**	0.03406	1.44	**0.02984**	**1.68**	0.01326	0.79	**0.04072**	**3.46**
0.00050	0.91			0.00073	1.51			0.00010	0.47		
	1.10				1.20				**1.96**		

increase major crime by 2%. Even this small effect is an overestimate of the actual effect, assuming there is some variation across time.[11]

7. Summary and Conclusions

Since handguns can be used by criminals to cause crime and by citizens to deter crime, our equations estimate the net effect of guns on crime. Our overall conclusion is that guns have a numerically very small net effect on crime. The long-run analysis showed no significant effect on overall crime or on any of the crime categories aside from a very small positive effect on rape. The Granger causality analysis revealed no significant effect of handguns on crime, apart from a very small negative effect on assault. The results of the short-run analysis confirmed the overall finding of very small and generally insignificant effects of handguns on crime. These conclusions are reinforced by the fact that in Tables 4, 5, and 7 we estimate 60 coefficients relating handguns to crime, of which we find six significantly different from zero. This is exactly what one would expect to find, given a 10% significance level, by random chance alone.

In the Granger causality analysis of handgun ownership and the short-run handgun equations

[11] Even if the actual rate of gun ownership is measured perfectly, the coefficients are identified off of "switchers," rather than off the average gun owner. Since we control for fixed effects, we cannot estimate the effect of gun ownership on crime for individuals who either never owned a gun or who always owned a gun over our sample period. This means that we are estimating a "marginal effect" based on switchers, which may be quite different from the average effect of the nonswitchers.

Table 8. Short-Run Handgun Equations[a]

	Dependent Variable: GSSHG					Dependent Variable: PHG			
	2SLS		OLS			2SLS		OLS	
	Coeff	*t* Ratio	Coeff	*t* Ratio		Coeff	*t* Ratio	Coeff	*t* Ratio
Variable	1	2	3	4	Variable	5	6	7	8
CRMAJ	**0.0027**	**1.78**	0.0005	0.38	CRMAJ	0.0004	0.88	0.0004	1.59
GSSHG (−1)	**−0.4466**	**5.32**	**−0.4501**	**5.44**	PHG (−1)	**−0.4968**	**15.84**	**−0.4855**	**16.75**
GUNSAMM	**−25.3091**	**1.87**	**−23.7780**	**1.78**	GUNSAMM	−2.0598	0.91	−1.1431	0.62
AMRMMS	**14.9943**	**2.73**	**13.2705**	**2.46**	AMRMMS	**2.0560**	**3.05**	**1.8434**	**3.10**
Intercept	−0.8206	0.50	−0.6458	0.40	Intercept	0.2637	0.67	0.1428	0.41
H-W	**0.0074**	**2.78**			H-W	0.0005	1.62		
Overid		0.15			Overid		0.44		
CRMUR	0.0948	0.60	−0.0210	0.15	CRMUR	0.0261	0.47	0.0056	0.18
GSSHG (−1)	**−0.4426**	**5.26**	**−0.4527**	**5.41**	PHG (−1)	**−0.4963**	**15.80**	**−0.4841**	**16.68**
GUNSAMM	**−22.5767**	**1.68**	**−23.6320**	**1.76**	GUNSAMM	−1.8949	0.83	−0.9189	0.50
AMRMMS	**12.8922**	**2.43**	**12.8908**	**2.43**	AMRMMS	**1.8881**	**2.88**	**1.6217**	**2.80**
Intercept	−0.9738	0.56	−0.5264	0.31	Intercept	0.1561	0.43	−0.0866	0.27
H-W	0.3051	0.91			H-W	−0.0014	0.22		
Overid		0.18			Overid		0.45		
CRRAP	0.0041	0.08	−0.0215	0.48	CRRAP	−0.0124	0.63	0.0048	0.48
GSSHG (−1)	**−0.4507**	**5.44**	**−0.4515**	**5.46**	PHG (−1)	**−0.4967**	**15.79**	**−0.4837**	**16.66**
GUNSAMM	**−23.1326**	**1.67**	**−25.0566**	**1.82**	GUNSAMM	−1.9618	0.86	−0.9548	0.52
AMRMMS	**12.8612**	**2.42**	**13.0471**	**2.46**	AMRMMS	**1.9166**	**2.92**	**1.6337**	**2.82**
Intercept	−0.6445	0.39	−0.4125	0.25	Intercept	0.1212	0.34	−0.0879	0.28
H-W	0.0854	0.83			H-W	−0.0004	0.69		
Overid		0.18			Overid		0.45		
CRROB	0.0041	0.60	−0.0022	0.34	CRROB	0.0002	0.09	0.0005	0.37
GSSHG (−1)	**−0.4496**	**5.41**	**−0.4515**	**5.45**	PHG (−1)	**−0.4958**	**15.80**	**−0.4842**	**16.69**
GUNSAMM	**−23.0300**	**1.72**	**−23.6627**	**1.77**	GUNSAMM	−1.9346	0.85	−0.9240	0.50
AMRMMS	**12.9927**	**2.44**	**12.8362**	**2.42**	AMRMMS	**1.9110**	**2.92**	**1.6313**	**2.82**
Intercept	−1.2594	0.65	−0.2556	0.13	Intercept	0.1203	0.33	−0.0695	0.22
H-W	**0.0583**	**2.93**			H-W	−0.0001	0.39		
Overid		0.19			Overid		0.45		
CRASS	−0.0003	0.07	−0.0038	0.81	CRASS	0.0032	1.83	0.0012	1.24
GSSHG (−1)	**−0.4512**	**5.44**	**−0.4544**	**5.49**	PHG (−1)	**−0.4996**	**15.88**	**−0.4861**	**16.74**
GUNSAMM	**−23.7955**	**1.65**	**−27.3825**	**1.93**	GUNSAMM	−1.5680	0.69	−0.9098	0.49
AMRMMS	**12.9696**	**2.39**	**13.7648**	**2.55**	AMRMMS	**1.8487**	**2.82**	**1.6195**	**2.80**
Intercept	−0.5540	0.31	−0.0137	0.01	Intercept	−0.0647	0.18	−0.1186	0.38
H-W	**0.0241**	**1.97**			H-W	−0.0002	0.42		
Overid		0.18			Overid		0.43		
CRBUR	**0.0034**	**1.90**	0.0012	0.81	CRBUR	0.0004	0.67	0.0006	1.63
GSSHG (−1)	**−0.4502**	**5.40**	**−0.4506**	**5.46**	PHG (−1)	**−0.4963**	**15.83**	**−0.4850**	**16.73**
GUNSAMM	**−29.8697**	**2.16**	**−25.8070**	**1.90**	GUNSAMM	−2.1250	0.93	−1.2215	0.66
AMRMMS	**16.1965**	**2.89**	**14.1076**	**2.57**	AMRMMS	**2.0706**	**2.97**	**1.9237**	**3.17**
Intercept	0.2381	0.14	−0.2962	0.18	Intercept	0.2829	0.65	0.2148	0.59
H-W	**0.0070**	**2.18**			H-W	0.0001	1.14		
Overid		0.15			Overid		0.45		

All variables measured as first differences (not logs), coefficients in bold are significant at the 0.10 level (two-tailed); (−1) indicates one-period lag. State and year dummy variables and other control variables were not significant. 2SLS indicates two-stage least squares estimation. The instruments are the same as those used in the crime equations in Table 7 above. Overid is the Basmann *F* test for overidentifying restrictions. Since none of the values are significant, the two-stage least squares models appear to be properly identified. H-W is the coefficient on the predicted value of the relevant crime in the Hausman-Wu test for specification error. Significance indicates that the OLS estimates may not be consistent. Regressions weighted by population. The results are unchanged if all variables are measured as first differences of logs.

[a] Bold coefficients are significant at the 10% level (two-tailed).

(Tables 6 and 8), the estimated equations indicate that handguns are relatively sensitive to crime rates. The significant coefficients are all positive, implying that a continuation of the current downward trend in crime will tend to reduce gun levels. However, we estimate 48 coefficients relating handgun ownership to crime, of which only four are significant at the 0.10 level, somewhat less than expected by chance alone. Therefore, we cannot conclude with confidence that crime causes handgun ownership.

We have replicated the analyses using various measures of gun ownership including overall gun prevalence (long guns as well as handguns, GSSGUN), imputed values of overall gun prevalence (PGUN), and percentage gun suicide. Our results are consistent throughout. The estimated net effect of guns on crime, however guns are measured or modeled, is generally very small and insignificantly different from zero.

In conclusion, we find that handguns have no significant effect on crime. This result can be interpreted in two ways. It could be the result of criminals, as opposed to guns, causing crime. In other words, criminals may simply use the tools available to them. If guns are readily available, they use guns, if not, they use other weapons, the rate of crime being unaffected by the presence or absence of guns. On the other hand, criminals certainly acquire guns to commit crimes and citizens also acquire guns to protect themselves from crime. There may be a rough equilibrium between criminals who use guns in the commission of crime and ordinary citizens who use guns to defend themselves and deter crime.

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