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Firearms and the Decline of Violence in Europe: 1200-2010

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Abstract

Personal violence, has declined substantially in Europe from 1200-2010. The conventional wisdom is that the state's monopoly on violence is the cause of this happy result. I find some evidence that does not support this hypothesis. I suggest an alternative hypothesis that could explain at least some of the reduction in violence, namely that the invention and proliferation of compact, concealable, ready-to-use firearms caused potential assailants to recalculate the probability of a successful assault and seek alternatives to violence. I use structural change models to test this hypothesis and find breakpoints consistent with the invention of certain firearms.

Keywords: firearms, violence, Europe, history, structural change models

1. Introduction

It is now taken for granted that crime, especially personal violence, has declined substantially in Europe from the Middle Ages to the present (Johnson & Monkkonen, 1996; Sharpe, 1996; Malcolm, 2002; Pinker, 2011). The best source of the data demonstrating this fact is Eisner (2003) who compileda large data set on homicide rates from 1201 to 1971 from several European countries. Most of the data come from England, although Germany and the Netherlands are well represented (Note 1). I have supplemented Eisner's data set with observations from London from 1631 to 1897 (Monkkonen, 2011) and data for Kent from Cockburn (1991). Finally I have added modern English data (1898-2010) taken from official sources and recent data (1995-2010) from the same set of countries that are represented in the original Eisner data set to complete the time series. The data are presented in Figure 1 below. All homicide rates in this paper are expressed as rates per 100,000. The homicide rates in Figure 1 are expressed in logs to reduce the considerable variance of the data. In fact, the homicide rate ranges from a maximum of 190 in Germany in 1409 to 0.06 in London from 1834-1836.

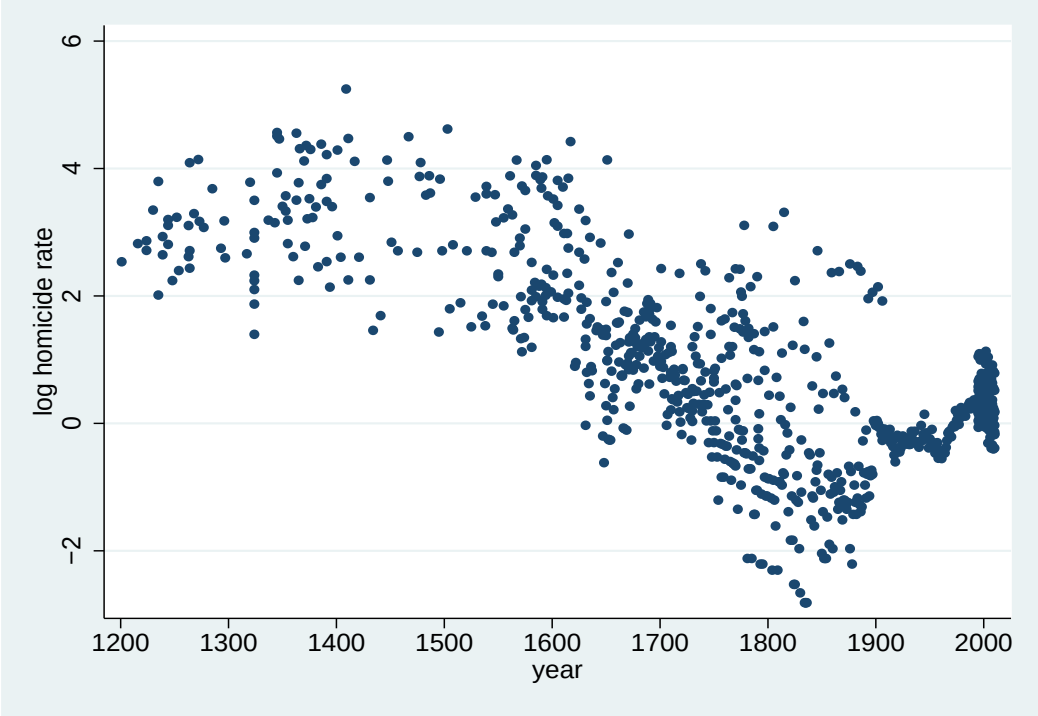

Figure 1. Homicide Rates, Europe, 1201-2010

While homicide rates today are much lower than they were in the 13th century, they do not appear to be falling continuously. The trend from 1200 to at least 1500 appears to be slightly upward, or at best constant. There also appears to be an upward trend since 1900. Table 1 presents means by centuries to get a better idea of the pattern (Note 2).

Table 1. Homicide rates by century

Century	Homicide Rate
1200s	22.68
1300s	36.84
1400s	40.79
1500s	20.28
1600s	7.84
1700s	2.48
1800s	1.78
1900s	1.18
2000s	1.41

What theory explains the decline in homicide from1500 to 1900? The conventional wisdom (Johnson & Monkkonen, 1996; Pinker, 2011) attributes the decline in personal violence to the "civilizing process" first suggested by Elias (1939) who hypothesized that the primary cause was the transformation of Europe from a large number of fiefdoms in the Middle Ages to a small number of large, centralized nation states under a single monarch. The centralized state instituted and enforced a monopoly on violence, known as the king's peace. Elias also conjectured that the centralization of power transformed independent noble warriors into courtiers dependent on the whims of the monarch. Instead of competing against each other with violence, they competed for the monarch's favor by mastery of complex rules of etiquette. The resulting courteous behavior trickled down

first to the bourgeoisie and then to the lower classes, eventually reducing violence overall. Finally, Elias suggested that the replacement of an economy based on the barter of agricultural products by an economy based on manufacturing and monetary exchange through markets also caused violence to decline. The combination of these three factors created what Elias called the civilizing process: "It was shown how the compulsion of competitive situations drove a number of feudal lords into conflict, how the circle of competitors was slowly narrowed, and how this led to the monopoly of one and finally—in conjunction with other mechanisms of integration such as processes of increasing capital formation and functional differentiation—in the formation of an absolutist state. This whole reorganization of human relationships went hand in hand with corresponding changes in men's manners, in their personality structure, the provisional result of which is our form of 'civilized' conduct and sentiment" (Elias, 1939, p. 231).

According to Pinker (2011), "Elias traces the centuries-long sequence in which courtesy percolated down from aristocrats dealing with the court to the elite bourgeoisie dealing with the aristocrats, and from them to the rest of the middle class. He summed up his theory, which linked the centralization of state power to a psychological change in the populace, with a slogan: Warriors to courtiers" (p. 75).

Despite Elias' apparent success, there are a few problems with his theory. "Belgium and the Netherlands were at the forefront of the decline, yet they lacked strong centralized governments. When Sweden joined the trend, it wasn't on the heels of an expansion in state power either. Conversely, the Italian states were in the rearguard of the decline in violence, yet their governments wielded an enormous bureaucracy and police force" (Pinker, 2011, p. 79). Barraclough (1982) thinks that Elias exaggerates the influence of the monarchy, the extent of feudal anarchy, and the ability of absolute rulers to impose their will. Roth (2009) suggests that, "… the civilization thesis does not fit the evidence. Once the impact of modern medicine on mortality is taken into account, it becomes clear that homicide rates in Europe were no higher through much of the medieval and early modern period than during the interwar years of the twentieth century … With modern wound care … three of every four homicide victims killed before 1850 would probably survive today. Modern people are more successful at saving lives, but they are not less violent" (p. 12). Finally, with respect to Elias' third strand, markets and money have existed in Europe since well before the 11th century.

In any case, the civilizing process is a long run theory. Most English legal scholars agree that the changeover from a system of compensation for crimes negotiated between the victim and the perpetrator, or their families or groups, customary in the Anglo-Saxon period, and the beginning of the common law administrated by judges appointed by the King, occurred during the reign of Henry II, 1133-1139 (Musson, 2009). However, even in Anglo-Saxon England, Alfred the Great (871-899) and Edward the Elder (899-924) both attempted to enforce a king's peace (Hudson, 2012, pp. 172-175). "Revenge slaying in the context of homicide, implicitly accepted in the late ninth-century laws of Alfred, was significantly restricted in the tenth… by the later twelfth century and quite possibly considerably earlier, homicide was a plea under royal jurisdiction, leaving only some residual claims to compensation on the part of the victim's family" (Hudson, 2012, p. 11). Thus, if the institution of the king's peace is the crucial factor in reducing violence, the breakpoint should have come before 1200, the beginning of the available data on homicide. Elias's theory is consistent with a slow and continuous decline in homicide with no breakpoint after 1200. As Table 1 demonstrates, the decline in homicide has not been continuous and there appears to be a breakpoint around 1500. The theory is also not consistent with the increase in violence in Europe, especially England, in the 20th Century.

According to the British historian James A. Sharpe, "This drop [in homicide], which has been noted in all of the relatively few areas for which relevant evidence survives, remains inexplicable" (Sharpe, 1996, p. 22).

2. An Alternative Theory

An alternative explanation, first suggested by Joyce Lee Malcolm, is the invention of firearms. Referring to England, she writes, "Firearms—muskets, birding guns, and pistols—began to come into common use in the sixteenth century… From then until 1920 there were no effective restrictions on their possession. The two trends cross; violent crime continued to decline markedly at the very time that guns were becoming increasingly available" (Malcolm, 2002, p. 20). Malcolm does not go so far as to hypothesize that firearms caused the decline in personal violence. Instead she simply notes that the largest reduction in homicide in the history of England coincided with the introduction of firearms and that when firearms were most widely used and completely unrestricted, in the late 19th and early 20th century, England enjoyed historically low overall homicide rates (0.76 from 1901-1910, compared to 1.37 from 2001-2010).

It is possible that firearms caused the decline in homicide because of their utility as weapons of self-defense. The first compact, concealable, ready-to-use firearm was the wheel lock pistol. There is considerable evidence that

Leonardo DaVinci invented the wheel lock in 1495. The design was then taken to Germany by one of his assistants and put into production there (Foley, 1998). There is also some evidence that it was invented in Germany around 1500 (Blair, 1973). In any case, according to Foley et al. (1983), "… there is clear evidence that the wheel lock was known in Germany by 1505" (p. 414). Some of this evidence is a diagram of a wheel lock from a 1505 German manuscript (Foley et al., 1983, p. 400; Morin, 1979, pp. 83-84) and a book of accounts which reports the purchase of a wheel lock in Hungary in 1507 (Blair, 1973, p. 35; Morin, 1979, pp. 84-85).

The wheel lock mechanism consisted of a steel wheel which was wound up against a spring with a key (called a spanner), like a wind-up toy, except that the spring was so strong that it only took a partial turn to cock it (Rimer, 2001, p. 9). Pulling the trigger released the wheel to spin against a piece of iron pyrite held in a clamp. The result, much like a modern cigarette lighter, was a shower of sparks igniting the primer in the flash pan and firing the gun. By 1517 wheel lock pistols had become so common that the Holy Roman Emperor Maximilian I banned them. "Inasmuch as certain persons in our territories of Lower Austria are in the habit of carrying self-striking hand-guns that ignite themselves which we are on no account prepared to allow… our nobles, stewards, administrators, chief justices, mayors and judges should under no circumstances permit such guns to be carried" (Morin, 1979, p. 85). This is almost certainly the first gun control law.

According to Pollard (1973),

> The wheel lock … was a compact, readily portable projectile weapon which could be concealed and would kill a man before he could come to handgrips or within stabbing distance. This was astoundingly important. Here for the first time was a means of using a gun for instant self-defence. It must have produced an enormous sensation for it suddenly altered the whole condition of affairs for the weaker man. … It was a predatory age, but the invention of the wheel lock introduced a totally new factor in the equation. [A man] could produce a pistol from beneath his cloak—and marauders would keep a respectful distance. … The wheel lock, though not as dependable as a modern firearm, was not very much slower to bring into use. It discounted much of the advantage of surprise and increased the risks of the attackers (pp. 18-19).

Also, firearms were feared in Early Modern Europe even more than they are today. They were loud and shot smoke and flames as well as bullets, and could be loaded with the equivalent of buckshot or even broken tobacco pipes or spoon handles (Rimer, 2001, pp. 16-17; Kirkton, 1817, p. 239). According to Don Quixote, a firearm was a weapon of cowards, a device that, "… may take the life of a valiant knight, … when amid that courage and fire that is kindled in the breasts of the brave suddenly there comes a random bullet, fired it may be by someone who fled in terror at the flash of his own accursed machine …" (Cervantes, 1949, pp. 342-343). According to Pollard, "Firearms of all kinds were held in great awe by all classes, for they were looked on as markedly unchristian and likely to inflict an inevitably fatal wound" (Pollard, 1973, p. 18). Given the primitive medical knowledge of the time, even a minor bullet wound in a relatively unimportant and otherwise non-vital spot would frequently lead to blood poisoning and eventual death. The mere possibility of encountering such a deadly weapon might be expected to deter potential assailants.

Even in the United States today, criminals are reluctant to encounter armed victims. In 1981 Wright and Rossi interviewed 1874 incarcerated felons in ten states. Eighty-one percent agreed with the statement, "A smart criminal always tries to find out if his potential victim is armed". Thirty-four percent report being, "scared off, shot at, wounded or captured by an armed victim (Wright & Rossi, 1986, pp. 132-155). Using the same data, Kleck found that, among criminals who had committed violent crimes or burglaries, 42 percent had been deterred during an attack by an armed victim and 56 percent agreed that, "most criminals are more worried about meeting an armed victim than they are about running into the police" (Kleck, 1997, p. 180).

All fifty states in the United States now allow individuals to carry concealed weapons. According to Lott and Mustard (1997), "The use of concealed handguns by some law-abiding citizens may create a positive externality for others. By the very nature of these guns being concealed, criminals are unable to tell whether the victim is armed before they strike, thus raising the criminals' expected costs for committing many types of crimes" (p. 4).

After the invention of the pistol, for the first time in history, the physically weak were placed on equal footing with the strong. From this point on, potential assailants had to weigh the risk of serious injury or death if the intended victim turned out to be armed. The wheel lock pistol was an enormous advance in the technology of self-defense. Of course, criminals could also acquire firearms, reducing the advantage of the armed victim. However, even if both the assailant and the victim are armed, the physically weaker victim is still better off than

before because the playing field is at least even, rather than tilted in favor of the larger, stronger, more aggressive assailant.

To have an appreciable effect on the homicide rate, there must be enough firearms distributed among the population of potential victims to generate a significant probability of harm to the assailant. We know that there were enough wheel lock pistols in 1517 to cause an attempted ban in the Holy Roman Empire. There is also evidence that by 1541 wheel lock pistols were in widespread use in England in the form of an English statute attempting to limit their use. A stream of legislation over the next 75 years tried unsuccessfully to regulate the increasing supply of pistols in England (Cockburn, 1977, p. 58).

The flintlock, familiar to most people from the US Civil War and pirate movies, was invented by the French gunsmith Marin le Bourgeoys sometime between 1610 and 1615 (Lenk, 2007, p. 31). It was the standard firearm technology for 250 years, eventually replaced by revolvers and breech loading rifles in the second half of the 19th century. Like wheel locks, flintlock pistols could be carried loaded, primed, concealed, and ready for instant use. For personal self-defense, flintlocks had all the advantages of wheel locks and were simpler, cheaper, and more durable. In addition, the flintlock could be cocked with the thumb rather than wound up with a separate tool, allowing it to be used with one hand. The flintlock technology spread rapidly. Table 2 shows prices paid for a pair of pistols in England between 1582 and 1759. The data come from several sources, most prominently Rogers and Rogers (1866-1902).

Table 2. Price of a pair of pistols 1582-1753

Year	Shillings Price	Pounds 2010	Dollars 2010
1582	12	136	207
1596	20	158	240
1620	22.5	183	278
1626	24	171	260
1631	50	302	459
1642	17	115	175
1650	18	97	147
1652	18	108	164
1659	18	99	150
1672	63	411	625
1674	16	90	137
1676	19	126	192
1678	15.4	93	141
1699	5	27	41
1703	69.5	459	698
1706	20	131	199
1709	29	154	234
1746	105	637	968
1753	36	214	325
mean	30	196	297
median	20	136	207

Conversion to 2010 prices was done using the Measuring Worth website (Note 3) and the July 1, 2010 dollar/pound exchange rate of 1.52. All data, data sources, and data manipulations are explained in data notes available at http://cemood.people.wm.edu/Firearms_and_Violence.zip

These prices may be overstated. Most of these prices include decorative wooden carrying cases. Also, most come from the evaluation of the estates of aristocrats such as Prince George of Denmark and the Duke of Richmond, who could be expected to have very expensive firearms as well as the best furniture, china, etc. Of more interest for our purposes, the Duke of Richmond's 1672 estate lists "Six cases of Ordinary pistols & 2 Carbines 4 12 0" (Kent Archeological Society, 1887, p. 400). Since a case of pistols is a matched pair in a box, this is a group of six pairs of pistols and two short barreled rifles suitable for use on horseback. The same inventory lists three carbines valued at two pounds, so that a carbine is worth about 13 shillings, implying that the pistols were valued at just under 13 shillings per pair. This translates to £85 or $129 in 2010 dollars which implies that ordinary flintlock pistols were very affordable by today's standards. The median price is 20 shillings or $207 in 2010 dollars, well below the price of most handguns today. A farm laborer in 1672 earned 10 pence per day (Clark, p. 26). The worker could buy a 13 shilling pair of pistols from the Duke's estate with 16 day's wages. In 1664 a foot soldier was paid 18 pence a day (Malcolm, 2002, p. 49). He could buy a pair of pistols with two weeks wages. Kirkton (1817, p. 230) reports that in 1666 a "poor workman" in Scotland wounded a soldier by shooting him with a pistol loaded with pieces of broken tobacco pipe and that other workmen in the group also had pistols (Note 4). Malcolm (1994, pp. 79-81) cites many 17th century English court documents where people of humble means such as servants, farmers, carpenters, laborers, bricklayers, blacksmiths, etc., owned firearms as evidenced by the fact that they were charged with a firearms offense. Hoffman (2011, Tables 1-2, pp. 45-47) estimates that the total factor productivity of pistol manufacturing was increasing at a rate of 0.8 to 1.1 percent per year for the period 1556-1706 indicating a substantial and continuing increase in supply and consequent drop in the relative price of pistols.

Pistols were common enough to be represented in the popular culture. Shakespeare has Falstaff hiding a bottle of wine in his pistol case in *Henry IV, Part I*. In the 1619 Spanish play *The Suspicious Truth* a complicated chain of events results in a flintlock pistol going off accidentally, revealing the protagonist's location. The audience was expected to be entirely familiar with its operation (Lavin, 1965, pp. 159-160). Pistols also figure prominently in the 1631 Jacobean play *The Duchess of Malfi*.

The Verney family history (Verney, 1904) recounts several instances involving firearms. For example, a Mr. Munis described as, "… very particular about his sword and his carabine, his pocket pistols and his screwed pistols…" (Verney, 1904, p. 270). In 1655 Sir Ralph Verney was arrested as a suspected Royalist. He reports that, "The Soldiers … used me very civilly, yet they tooke all the pistols & swords in the house…" (Verney, 1904, p. 12). Sir George Wheler told the Verneys of his trip from Oxford to London in 1672. "… I came into a deep and narrow lane … I could see neither way before me nor sky above me, nor anything about me. Having pistols before me, I drew one and held it in my hand, so that I could span it in a moment for fear of a surprise" (Verney, 1904, p. 345). In 1661 Samuel Pepys reports owning both a sword and a pistol (Pepys, 1905, p. 64).

As gun ownership spread, the risks associated with violent behavior increased, leading to a predictable decline in homicide. At the same time, there was no significant increase in firearm homicides. Sharpe (1983, Table 13, p. 128) reports that, in Essex between 1620 and 1680, guns were used in only 11 percent of homicides and 68 percent of those accused were acquitted, usually on the basis of accidental death. The most common weapons used in the commission of homicides were hands and feet, sticks, staffs, and other blunt instruments. According to Sharpe (1983, p. 129), "It is, moreover, difficult to relate the deaths due to shooting to an increase in criminal homicide resulting from weapon carrying". The dearth of homicides by firearm is consistent with people actively avoiding conflict with potentially armed individuals.

3. A Closer Look at the Data

Homicide rates were constant or increasing from 1200 to 1500, indicating that the civilizing process was not particularly effective in Europe during that time. The first great decline appears to take place in the 1500s when homicide rates fell to half of those in the previous century. The process continues into the 1600s and 1700s where homicide rates fall by another 50 percent or more in each century. If homicide rates are constant or increasing and then suddenly plummet, it is incumbent upon the analyst to suggest what might have happened at that time that might explain the phenomenon.

To determine the turning point, if any, in the homicide rate time series, it is necessary to do some preliminary cleaning up of the data. The Eisner data set consists of observations of many different cities and counties in several countries (Note 5). There are frequently several observations for different geographical areas for the same year. I collapsed the Eisner data to a single observation per year by taking the mean across all geographic entities for each year. The result is shown in the bottom frame of the following graph with the original data from Figure 1 shown in the top frame for comparison. The two graphs look very much alike.

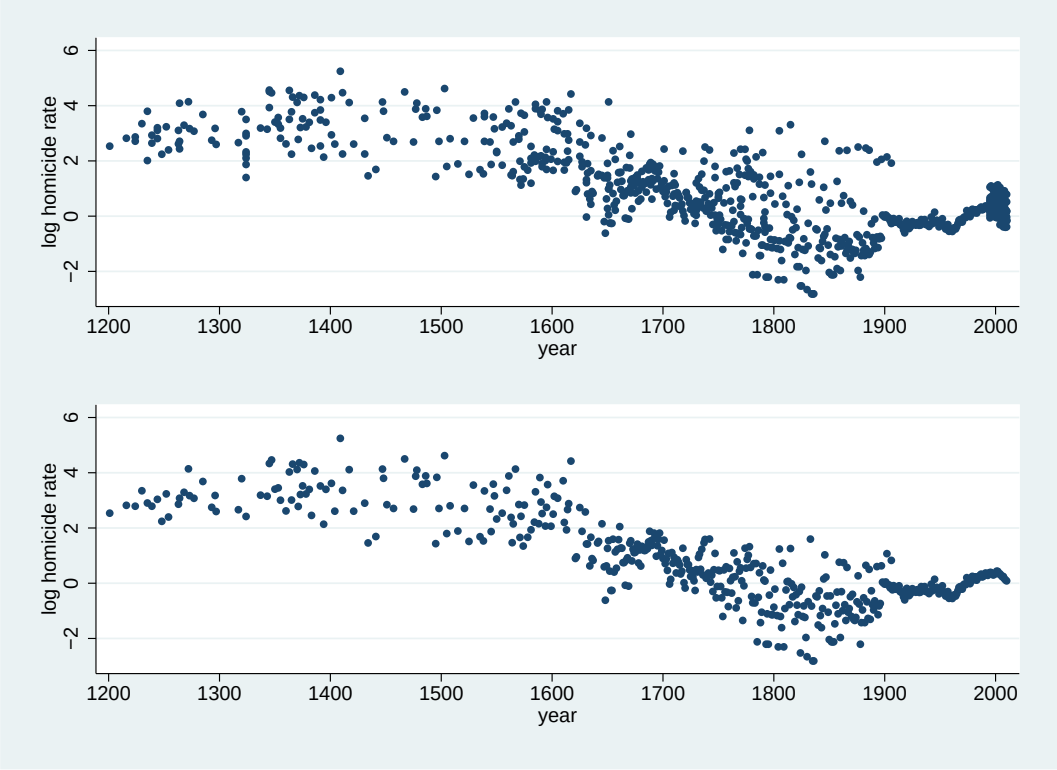

Figure 2. Homicide and log homicide rates, 1201-2010

The obvious test of the concealable firearms hypothesis is the Chow (1960) test which requires that the breakpoint be specified exogenously. There are two exogenous dates suggested by the theory: 1505, the earliest year the wheel lock pistol was known, and 1610, the earliest year the flintlock could have been invented.

A potential complicating factor is the effect of war on homicide. A foreign war typically reduces violence at home, at least temporarily, because many of the young men who would otherwise be committing homicide are not present. The effect of a domestic war could be in either direction. The English Civil War, for example, took place against a background of rapidly declining homicide rates. I estimated the Chow test equation including a group of dummy variables corresponding to the dates of all the major European wars. The regression revealed that, of all the war dummies, only the French Revolution and Napoleonic Wars 1792-1815 and the Crimean War 1853-1856 had significant coefficients. Also, there was no significant break in trend in 1505. The insignificant war dummies and the spline for 1505 were dropped from the model. The dropped variables were tested jointly and found to be insignificant (F=0.71, p=0.73), justifying eliminating them as a group. The resulting Chow test equation is presented in Table 3 below. The coefficients on the dummy variables for 1505 and 1610 and the spline for 1610 are highly significant both individually and jointly (F=37.93, p=0.000).

Table 3. Chow breakpoint regression

Variable	Coefficient	T-ratio
Constant	**2.962**	**13.96**
Trend	0.002	1.64
Dummy 1505	**-1.081**	**-3.85**
Dummy 1610	**-1.578**	**-9.55**
Spline 1610	**-.006**	**-5.17**
Napoleonic War	**-0.922**	**-5.21**
Crimean War	**-1.634**	**-3.95**

R-square	0.73
F	**215.12**
N	493

Bold indicates significant at the .05 level. The results indicate that there is a significant downward shift in the mean after 1505 and again after 1610. In addition, the trend, which was positive but insignificantly different from zero, does not become negative until after 1610. See Figure 3 below.

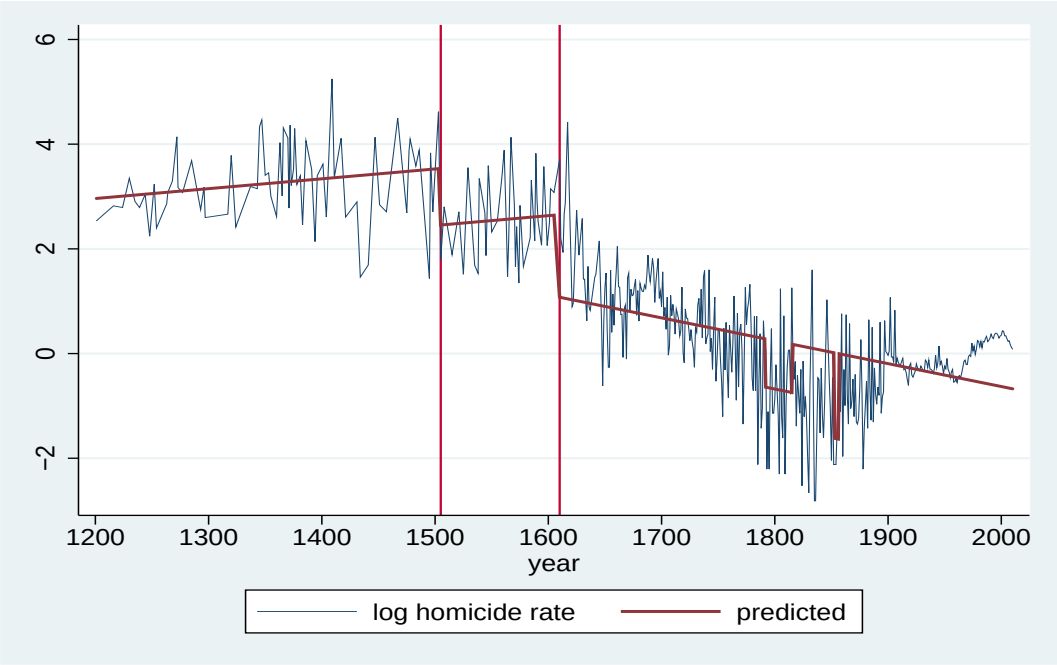

Figure 3. Chow breakpoint model

An obvious criticism of the Chow breakpoint analysis is that other years could also have been significant in a similar test. A test for structural change that is not dependent on the choice of a particular year and is not subject to the criticism that the breakpoint is potentially endogenous is the Bai-Perron (BP) multiple structural change test (Bai & Perron, 1998, 2003). The BP procedure tests for the number of structural breaks and the dates of those breaks. The testing algorithm is as follows. Test each year for a breakpoint. The year with the smallest error sum of squares is selected and tested using a standard F-statistic. It is designated as a breakpoint if the F-test is significant. Bai and Perron (2003) provide the nonstandard critical values. If a breakpoint is found, the subsamples are tested for breakpoints. The sample is further subdivided if additional breakpoints are found. Bai (1997) recommends that the subsamples be repartitioned. For example, if one breakpoint is found, at T1, then the sample is subdivided into two subsamples. If the second subsample is found to have a breakpoint at T2>T1, Bai suggests that the first break at T1 be re-estimated on the subsample from 1 to T2 since the first break was found using the entire sample and the observations after T2 are apparently not from the same data generating process. For this reason I use the repartitioned results. Because the test cannot determine breaks at the endpoints, the researcher must choose the proportion of the data to trim off the ends of the sample. I use the default 15% trim parameter.

The BP test is also a falsification test of the firearms hypothesis if a significant negative breakpoint is found before the introduction of concealable firearms in 1505. The BP test indicated that there are two significant breaks, in 1621 and 1793. The break in 1621 is negative for both the intercept and the trend. The break in 1793 is negative for the intercept and positive for the trend. Adding a dummy and spline for 1621 and 1793 to the Chow test model in Table 3 revealed that the coefficient on the dummy for 1505 was still negative and significant. The spline for 1505 and the dummy and spline for 1610 were no longer significant. Dropping the 1505 spline and the 1610 dummy and spline (F=0.94, p=.42) yields the results presented in Table 4 below.

Table 4. Chow test with 1505, 1621 and 1793 breakpoints

Variable	Coeff	T-ratio
Intercept	**2.935**	**16.93**
dum1505	**-1.074**	**-4.64**
dum1621	**-1.190**	**-7.44**
dum1793	**-1.061**	**-6.78**
Trend	**0.002**	**2.18**
spline1621	**-0.012**	**-7.85**
spline1793	**0.016**	**11.19**
Napoleon	**0.355**	**2.03**
Crimea	**-0.871**	**-2.51**
Rsq	.81	
F	**265.55**	
N	493	

Bold indicates significant at the .05 level, two-tailed. The graph is shown below.

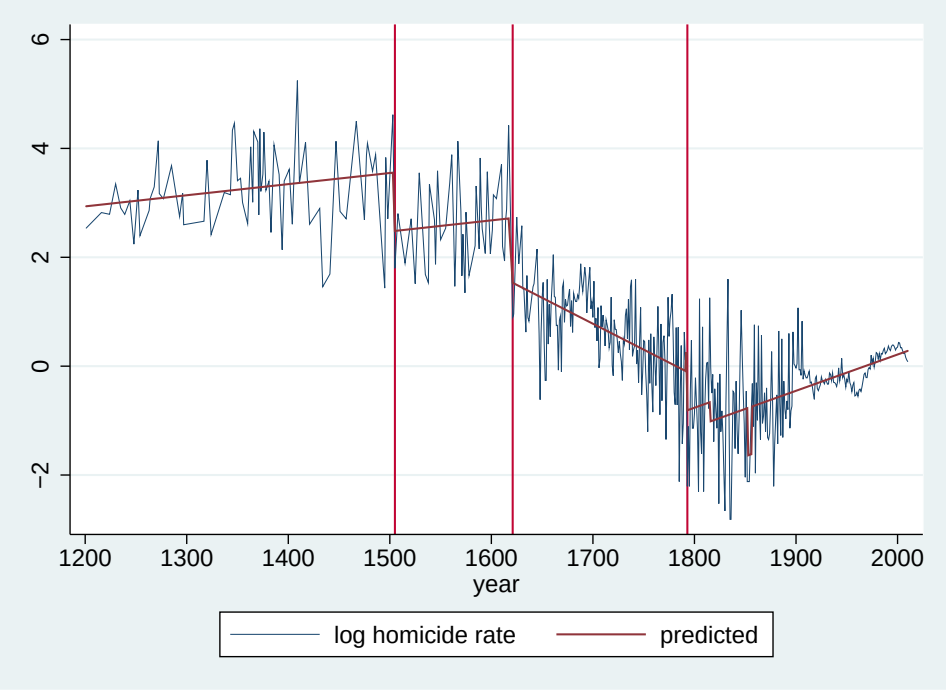

Figure 4. Breakpoints at 1505, 1621, and 1793

4. An Attempt at Ex-Post Theorizing

The breaks in 1505 and 1621 are clearly consistent with the firearms hypothesis and not consistent with the civilizing process theory. The fact that no breakpoints are found before 1505 fails to falsify the self-defense theory. The 1793 break consists of two parts, a negative shift in the mean and a positive break in trend. The break in trend is in the wrong direction to be the result of any of the strands of the civilizing process hypothesis. The negative break in mean In 1793 could be capturing some of the effect of the Napoleonic Wars which put young men who would otherwise be committing illegal homicide into the army where they committed legal homicide (Note 6).

The positive break in trend is a function of the higher homicide rates after 1793 and could be a function of the supply of firearms. Assume that an assault (A) can be either lethal, in which case it results in a homicide (H), or nonlethal in that the victim survives. Let α be the proportion of assaults that result in a homicide and assume that it is an increasing linear function of the stock of firearms (G),

$$H=\alpha A, 0<\alpha<1 \tag{1}$$

$$\alpha=\alpha_0+\alpha_1 G,\ 0<\alpha_0,\alpha_1<1 \tag{2}$$

Assume that firearms can either increase the number of assaults because they embolden the attacker or otherwise facilitate an assault, the "instrumentality effect" (Kleck & McElrath, 1991) or decrease the number of attacks because potential assailants are deterred by the risk of injury to themselves, the deterrent effect (Wright & Rossi, 1986; Lott & Mustard, 1997).

$$A=b_0+b_1 G+b_2 G,\ b_0>0,\ b_1>0,\ b_2<0 \tag{3}$$

Where b_1 is the instrumentality effect and b_2 is the deterrent effect. I assume that the deterrent effect is greater than the instrumentality effect, $|b_2|>b_1$. This assumption will be discussed below. Combining the equations yields the following.

$$H=\alpha_0 b_0+(\alpha_1 b_0+\alpha_0\beta)G+\alpha_1\beta G^2 \quad \text{where} \quad \beta=b_1+b_2<0 \tag{4}$$

Since b_0 is the level of homicide in the absence of concealable firearms, which we know was very high before 1500, a_0 is a relatively small fraction, and β is the sum of a positive and a negative parameter, I assume that $a_1 b_0+a_0\beta>0$ (Note 7).

The derivative is

$$dH/dG=(a_1 b_0+a_0\beta)+2a_1\beta G$$

This derivative is equal to zero if

$$G=G^*=(a_1 b_0+a_0\beta)/2a_1\beta,\quad G^*>0 \text{ if } a_1 b_0+a_0\beta>0 \tag{5}$$

The second derivative is,

$$d^2H/dG^2=2a_1\beta<0$$

which is negative, indicating that, under these assumptions, the homicide equation is a convex function reaching a maximum with G*>0. As the stock of firearms increases, the homicide rate rises because the lethality of attacks increases while the deterrent effect is quite small. Eventually the stock of guns reaches a critical mass such that the deterrent effect becomes dominant and as the stock of guns increases beyond G* the homicide rate falls continuously. Under these assumptions, there is nothing to stop the homicide rate from becoming negative as G goes to infinity. To avoid this I assume that the relevant range of G is limited, e.g., measured in per capita values, such that lethality does not exceed the unit value and assaults do not become negative.

If the instrumentality effect is greater than the deterrent effect, $b_1>|b_2|$ then

$$\beta=(b_1+b_2)>0$$

In which case, the homicide rate starts out high and increases at an increasing rate. There is no maximum. Since we observe the homicide rate falling after the introduction of firearms, I assume that the deterrent effect is greater than the instrumentality effect.

Under this theory the homicide rate peaked as firearms reached a critical mass and then decreased. After 1793 when homicide fell to historically low levels, people could have begun to feel safe enough to go about unarmed, thereby reducing the effective stock of guns. There is some evidence that this happened in England. Colin Greenwood reports that, "Prior to the passing of the [1903] Pistols Act, Members spoke frequently of their habit of carrying pistols and of their willingness to use them in self-defence … In later debates the point does not arise … the demand for firearms for protection almost disappears in the early twentieth century" (Greenwood. 1972, pp. 245-246). Homicide and assault rates in England were historically low around 1900, averaging 0.92 and 3.92 respectively from 1898 to 1910. Also, if governments began to reduce the effective stock of guns by a variety of gun control measures, the actual or the effective stock of guns would have declined, causing the homicide rate to increase. There is some evidence that this also occurred in England. The government in England

has been placing increasingly stringent controls on guns especially handguns, since 1920, reducing both the actual and the effective supply of firearms (Malcolm, 2002). The homicide rate in England in 1920 was 0.84 and the assault rate was 2.39. In 1999, the corresponding rates were 1.44 and 419.3 (Note 8). Thus both the homicide and assault rates increased as the effective supply of handguns declined.

It is also possible that the deterrent effect diminishes as the assault rate falls. At very low assault rates there are few potential homicides to deter. If the deterrent effect falls below the instrumentality effect after the attack rate falls below a certain level, the homicide rate could increase with the increasing stock of guns because of the continuing lethality and instrumentality effects.

An alternative explanation is that firearms became more lethal after 1793 with the invention of the revolver and other semiautomatic pistols and the replacement of black powder with more powerful modern gunpowder. On the other hand, modern medicine has made all weapons less lethal (Roth, 2009, p. 12). However, modern wound care began in the 19th Century. There were no advances in wound care around 1500 or 1600 that would explain the sudden decline in the homicide rate that occurred at that time.

It is also possible that the instrumentality effect was always greater than the deterrent effect in Europe and that the decline in homicide would have been even faster in the absence of firearms. This hypothesis implies that the civilizing process was going in reverse until 1500 when it suddenly changed signs and accelerated just at the time when concealable firearms were invented. Homicide fell in spite of the increasing number of firearms and this acceleration continued until 1793 when the civilizing process again reversed itself.

There could, of course, be other possible explanations of the 1793 breakpoint which coincides roughly with the beginning of the industrial revolution and the demographic transition in Europe, especially England (Hinde, 2003, pp. 187-191). Criminologists agree that the proportion of young males in the population is a good predictor of crime (Fox, 2000, Hirschi & Gottfredson, 1983). The rapid population growth characteristic of the beginning of the demographic transition expanded the proportion of people between 15 and 24, which could cause an increase in crime, including homicide. With respect to the industrial revolution, many historians have noted the bleakness of the lives of factory workers, their reliance on alcohol, and the psychological pressure necessary to convert a pre-industrial to an industrial work force, any of which could have caused the homicide rate to increase (Lane, 1974; Antonaccio & Tittle, 2007).

Finally, the 1793 breakpoint is also consistent with the theory that the public provision of services is inefficient relative to private production. This implies that the monopolization of violence by the state and the public provision of police services became increasingly inefficient over time, causing homicide to rise. “The fact that the [Anglo-Saxon] restitution-based system was replaced by a system dominated by public policing is not a reflection of the superior efficiency of government in production of a public good. Indeed, a clear implication of the analysis is that by taking the private right to restitution and increasing the private cost of cooperation, the only primary benefits of policing that remained for general citizens were common-access benefits … Consider two widely cited consequences of common property: (1) inefficient overuse or congestion of the common-access resources, and (2) under-investments by individuals in privately provided resources used to produce common-access attributes. Both clearly apply to criminal law enforcement …” (Benson, 1994, p. 260). Police forces as we know them today were first established in London in 1829. The average homicide rate in London from 1820 to 1829 was 0.26. From 2000 to 2009 the average London homicide rate was 2.28.

5. Robustness Checks

Preliminary unit root tests on the log homicide rate were inconclusive. The Augmented Dickey-Fuller (ADF) test and the DF-GLS test (Elliot, Rothenberg, & Stock, 1996) both indicated non-stationarity in levels. Adding a deterministic trend did not affect the ADF test but the DF-GLS test rejected the unit root hypothesis at the .10 level. The unit root hypothesis was rejected both in levels and with a trend by the Phillips-Perron unit root test. Since structural breaks can affect unit root tests (Perron, 1989). I did a test under the null that the log homicide rate is a unit root process around a deterministic trend with breaks at the dates indicated above. The unit root hypothesis was rejected indicating that standard hypothesis tests are justified (Note 9). Dropping the war dummies does not change the results of the tests reported in Tables 3 and 4. Adding a lagged dependent variable does not change the results. The use of a lagged dependent variable is somewhat problematic in that the homicide rate time series is irregular with varying gaps between successive observations. There are two ways of handling this problem: allowing irregular gaps between observations or forcing no gaps in the data. This is only a problem in models with lagged variables. I did it both ways. The results were the same.

The graphs show that the variance of the homicide rate is much lower after 1900 when the series switches from samples of places to national averages from official sources. I re-estimated the models reported in Tables 3 and 4

using heteroskedasticity consistent standard errors. The results were unaffected. Since serial correlation is a potential problem with any time series, I tested the regressions reported in Tables 3 and 4 for serial correlation using the Breusch-Godfrey LM test. I found significant serial correlation in the regression reported in Table 3 with and without the lagged dependent variable. There was also significant serial correlation in the regression reported in Table 4, which disappeared with the addition of a lagged dependent variable. I also re-estimated both models using heteroskedasticity and autocorrelation consistent standard errors (Newey & West, 1987) with and without a lagged dependent variable. The results were unchanged. The results were also unchanged when I re-estimated the regressions reported in Tables 3 and 4 using the data shown in Figure 1, without averaging across geographical units. As a check for non-linearity, I estimated a quadratic spline model and a cubic spline model. The Bai-Perron test found two breakpoints (1621 and 1819) for the quadratic spline and two breakpoints (1631 and 1897) using the cubic spline. The breaks at 1621 and 1631 were significantly negative and the breaks at 1819 and 1897 were significantly positive.

To see if the results were sensitive to a single country, I dropped each country in turn and re-ran the Chow tests. There are too many missing values in countries other than England to do the regressions by country. Dropping each country in turn does not change the results with respect to Table 3, except that when I dropped England, the coefficient on the 1610 dummy became significant only at the .10 level (p=.08). The coefficients on the 1505 dummy and 1610 spline were still negative and significant at the .05 level. Since England represents over half the sample, it might be expected that omitting it would have some effect. With respect to Table 4, the results are completely unchanged if England is dropped from the sample. There are enough observations to do the Chow test for England alone. However, there is a huge gap in the English data from 1375 and 1495. Nevertheless, when the Table 3 Chow test is estimated on England alone, the dummy for 1610 is negative and highly significant while the dummy for 1505 and the spline for 1610 are negative but significant only at the .10 level. The F-test for these variables as a group remains highly significant (F=11.37, p=0.000). With respect to Table 4, the only effect of estimating on English data alone is that the 1621 dummy becomes significant only at the .10 level (p=.053).

The BP test was somewhat sensitive to the choice of the trimming parameter. I re-estimated the BP test allowing the trim parameter to take the values 5, 10, 15, and 20 percent of the sample using both OLS and Newey-West standard errors, for both the simple model using only a constant and a trend and the model with the two war dummies, for both models with and without a lagged dependent variable, and for all models with and without repartitioning, a total of 64 tests. The tests identified the 1621 breakpoint in every case. The 1793 breakpoint was identified in every test in which the sample was repartitioned, but was replaced by a 1785 breakpoint in every case if the sample was not repartitioned. The 1505 breakpoint was identified 32 times. A break in 1495 was detected 24 times and a break in 1819 was found four times.

Since 1495 was identified as a breakpoint, I entered a dummy and spline for 1495 into the models shown in Tables 3 and 4. Neither the dummy nor the spline for 1495 was significant in either model while the other dummies and splines remained highly significant. The results in Tables 3 and 4 are unchanged if I use the 1785 breakpoint instead of 1793. The results are also unchanged if I add the 1819 breakpoint. Dropping the years after 1792 results in 1505 and 1621 being the only breakpoints. The same is true if the sample ends in 1870. Apparently the 1793 breakpoint is a function of the rise in crime after 1870. All results, programs and data are available from http://cemood.people.wm.edu/Firearms_and_Violence.zip

6. Conclusion

The weight of evidence is that there was a negative break in the mean European homicide rate around 1505, coincident with the invention of the wheel lock pistol, but the major effect was the significant and negative break in mean and trend around 1621, coincident with the introduction and proliferation of the flintlock. The positive break in trend in 1793 is not consistent with the civilizing process but is consistent with either a reduction in the effective stock of firearms or a decrease in the deterrent effect of firearms at low assault levels. It is also consistent with inefficiency in the state's monopoly on violence and a number of other hypotheses. It is possible that firearms outlived their usefulness as weapons of self-defense when the homicide rate fell to very low levels in modern Europe. The rise in homicide after 1793 could be the result of the lethality and instrumentality effects of firearms exceeding the deterrent effect at low assault levels.

The firearms theory is plausible in that concealable firearms could deter individuals from making assaults, it is testable using breakpoint analysis on the time series of homicide, and it is falsifiable in the sense that the discovery of negative breakpoints before the invention of concealable firearms could be interpreted as evidence

suggesting some other process was reducing homicide. The civilizing process theory is also testable and falsifiable in that positive breakpoints after 1200 could be interpreted as indicating the failure of the process.

Correlation is a necessary but not a sufficient condition for causality. The correlation of the breakpoints with the introduction of concealable firearms could be coincidental, but the fact that correlation can be spurious does not mean it is spurious in any given case. All one can do is provide a plausible theory of causation, a falsifiable hypothesis, and a corresponding hypothesis test. If the hypothesis does not reject, the theory survives for possible refutation later.

There is no reason to suppose that Elias' civilizing process has had no effect on homicide, but it is not possible with currently available data to identify the separate effect of firearms and the growth of government on homicide rates. In any case, the civilizing process theory is not consistent with the rise in violence between 1200 and 1500, it does not explain the sudden and precipitous decline and reversal of trend that occurred in the 16th and 17th centuries, and it is not consistent with the 1793 reversal of trend.

According to Pinker (2011), "[Elias] proposed that over a span of several centuries, beginning in the 11th or 12th and maturing in the 17th or 18th, Europeans increasingly inhibited their impulses, anticipated the long-term consequences of their actions, and took other people's thoughts and feelings into consideration. A culture of honor—the readiness to take revenge—gave way to a culture of dignity—the readiness to control one's emotions … The standards also trickled down from the upper classes to the bourgeoisie that strove to emulate them, and from them to the lower classes, eventually becoming a part of the culture as a whole" (p. 72). Obviously, it is much more important to inhibit your impulses and to take other people's thoughts and feelings into consideration when the other people are likely to be armed. The transition from a coarse and violent Medieval era to a more refined and gentle modern era does not have to be exclusively due to etiquette trickling down from the nobility. To quote Robert A. Heinlein (1942, p. 238), "An armed society is a polite society. Manners are good when one may have to back up his acts with his life".

Homicide was increasing before the invention of concealable firearms and decreasing after. While there may be many other theories, the sudden and spectacular decline in violence around 1505 and again around 1610-1621 is consistent with the theory that the invention and proliferation of concealable firearms was responsible, at least in part, for the decline in homicide. The landscape of personal violence was suddenly and permanently altered by the introduction of a new technology. The handgun was the ultimate equalizer. The physically strong could no longer feel confident of domination over the weak. The fact that potential assailants could not determine who among a set of possible victims was carrying a firearm generated an externality in which those that were armed protected those that were not and thereby multiplied the effectiveness of the stock of firearms.

> [The wheel lock] must have produced an enormous sensation, for it suddenly altered the whole condition of affairs for the weaker man. Till then he had always been subject to the personal element of muscular superiority. Any armour-plated robber knight and his gang of ruffians could raid into a merchant caravan. Small gentry were at the mercy of the turbulent local nobles. It was a predatory age but the invention of the wheel lock introduced a totally new factor into the equation … There are still countries where banditry, raiding and civil wars flourish, and if we argue from personal experience it is probable that in the Middle Ages a display of armament was as protective then as now (Pollard, 1973, pp. 18-19).

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Notes

Note 1. I am grateful to Randolph Roth for kindly sending me a machine readable copy of the Eisner data set.

Note 2. All programs and data used in this paper as well as notes describing the data sources and manipulations can be downloaded from http://cemood.people.wm.edu/Firearms_and_Violence.zip

Note 3. http://www.measuringworth.com/ppoweruk/

Note 4. http://books.google.com/books?id=tDBCAAAAcAAJ&pg=PA230&dq=pistolls

Note 5. The countries are, in order of the number of observations for each: England, Germany, Italy, Sweden, Netherlands, Switzerland, Ireland, Belgium, France, Spain, and Finland.

Note 6. The relatively high homicide rates in England from 1950 to 2010 are clearly not consistent with Elias' civilizing process theory. Also, the homicide rate counts neither the number of government sanctioned homicides in all the various European wars since 1200 including the millions killed in Europe in the two World Wars, nor the six million homicides perpetrated by the German government during the Holocaust.

Note 7. If this assumption is false, then the function falls continuously. The initial value is the maximum and there is no minimum.

Note 8. Homicide and assault data are from http://data.gov.uk/dataset/recorded-crime-data-1898-2001-02

Note 9. The t-ratio corresponding to the null hypothesis that the coefficient on the lagged dependent variable equals 1 is -12.02 which exceeds the Monte Carlo generated 5% critical value of -3.61. Details are available from http://cemood.people.wm.edu/Firearms_and_Violence.zip