Document Title: Gun Density Versus Gun Type: Did the Availability of More Guns or More Lethal Guns Drive up the Dallas Homicide Rate, 1980-1992?

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GUN DENSITY VERSUS GUN TYPE: DID THE AVAILABILITY OF MORE GUNS OR MORE LETHAL GUNS DRIVE UP THE DALLAS HOMICIDE RATE, 1980-1992?

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EXECUTIVE SUMMARY

Homicide rates in the United States began increasing sharply in the late 1980s and reached near record levels by the early 1990s. Though homicide rates have decreased from these high levels during the last few years, explanation of this phenomenon still remains a key challenge to crime control efforts. Recent homicide trends have been driven largely by trends in gun homicides. Gun availability, particularly among inner city young males, has therefore been implicated as one explanatory factor. Another hypothesis is that changes in the lethality of the criminal gun arsenal played a role in driving up homicide rates.

Social scientists have rarely examined consequences stemming from the availability and use of differentially lethal guns, despite empirical and theoretical grounds for believing that some guns are more lethal than others. However, a number of recent studies have linked increases in homicides to the growing use of semiautomatic and/or high-powered firearms by criminals. These studies imply that gun violence is becoming more deadly due to the substitution of more lethal firearms for less lethal firearms. Semiautomatic weapons permit a somewhat more rapid rate of fire than do non-semiautomatics, and they generally have larger ammunition capacities. Thus, offenders using semiautomatics can potentially fire more times and at a more rapid rate, thereby increasing the likelihood that they hit one or more victims at least once. High powered weapons, such as shotguns, centerfire rifles, and large caliber handguns, inflict more lethal wounds.

Using data from Dallas, Texas for the period 1980-1992, this

study examines the relationship between trends in deadly gun violence, overall gun availability, and the availability of more lethal types of guns. As in many cities around the nation, homicide levels rose in Dallas during the late 1980s and early 1990s, a trend primarily attributable to a rise in gun homicides. During the early 1990s, Dallas had one of the highest homicide rates among America's largest cities.

Dallas' crime gun arsenal grew substantially more lethal from 1980 to 1992 as measured by changes in the types of guns confiscated by police. Confiscations of semiautomatics and high powered firearms grew as a percentage of all confiscated guns, as did weapons combining these characteristics. These trends were driven largely by trends in handgun confiscations. To illustrate, semiautomatic handguns rose from approximately 25% of confiscated handguns in the early 1980s to 65% in 1992. Likewise, large caliber handguns (defined as handguns larger than .32 caliber) accounted for approximately 45% of confiscated handguns in the early 1980s and rose to about 60% by the early 1990s. Large caliber semiautomatic handguns increased nearly fourfold in relative terms, rising from under 10% of confiscated handguns in 1980 to 38% in 1992.

Bimonthly and quarterly time series analyses indicated that trends in the use of high powered weapons, both semiautomatic and non-semiautomatic, exerted a positive influence on gun homicides in Dallas. In quarterly analyses, for example, a one unit increase in the percentage of confiscated handguns having a large caliber was associated with approximately one additional gun homicide per quarter. However, gun lethality trends explained only a modest portion of the variation in gun homicides during the study period.

The rising use of semiautomatic weapons did not clearly influence gun homicides. And although there was some evidence that the use of semiautomatics was associated with a higher fatality rate per gun attack, this rate declined during the later years of the study period as semiautomatics were becoming more prominent. Measurement of the fatality rate was problematic, however, most notably because the rate was based on all gun aggravated assaults, including those resulting in no gunshot wounds and even those with no gun discharges. For this and other reasons, the fatality rate results should be treated much more tentatively than the gun homicide analyses.

Finally, overall gun availability, measured by the percentage of robberies committed with guns, remained relatively stable during this time (generally varying between 40% and 50%) and did not significantly influence gun homicide trends. These results suggest that the availability of more lethal guns among criminal/high risk groups (particularly high powered weapons) exerted more influence on gun homicides in Dallas than did the general availability of firearms among these groups, at least during this particular time period. Nevertheless, Dallas' homicide trends appear to have been driven primarily by factors other than changes in weaponry.

The results should be qualified on a number of grounds. For instance, the gun lethality measures were based on all confiscated guns rather than guns used in violent crime. It is possible that more specific gun lethality measures tied to particular groups of crimes or offenders might produce different results. Moreover, available data did not permit a direct test of the hypothesis that offenders using semiautomatics fire more shots and inflict more wounds in gun attacks. Finally, our ability to control for other potentially important variables affecting the outcome measures was limited.

Notwithstanding, this study has shown that the crime gun arsenal has become more lethal in recent years, and there is evidence that this trend has had negative consequences on public safety in Dallas, and presumably elsewhere. Indeed, the results of this study are very similar to those produced by an earlier study examining recent trends in gun lethality and gun violence mortality in Kansas City, Missouri.

This study has modest implications for policy but can inform debates over regulation of different types of weaponry. By extension, for example, the findings regarding high powered weapons imply that restrictions on the distribution of new forms of especially lethal ammunition may have beneficial preventive effects (this is related to firearm stopping power). At the same time, this study raises questions about the potential impact of measures directed at semiautomatic weapons, such as the federal government's ban on large capacity ammunition magazines and its penalty enhancements for crimes committed with semiautomatics.

Future research efforts may build on this study in a number of ways. Most notably, there is a need for more intensive incident-based research to examine the role of firearm characteristics, such as semiautomatic firing and ammunition capacity, in determining gun attack outcomes. Additional efforts by public officials and researchers to track changes in overall crime weaponry and weaponry used by particularly dangerous groups may yield important data. A methodological implication is that future studies on gun availability and violence should, wherever possible, take into account the availability of differentially lethal types of guns. Such research can help us to better understand the consequences of the evolving technology of personal violence and provide insights into the utility of different law enforcement and legislative responses to gun crime.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF FIGURES

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1. INTRODUCTION

Criminologists have long recognized the importance of determining the impact of weapon types on the volume, patterns, and lethality of violence (Cook 1991). Accordingly, many researchers have examined the consequences of criminal gun use at both the aggregate and individual levels (for reviews, see Cook 1991; Kleck 1991; Wright et al. 1983). An emerging issue, however, concerns the use of specific types of gun varying in lethality and the impact this may be having on injuries and deaths from criminal violence.

Firearm homicides increased dramatically throughout the nation during the late 1980s and early 1990s, and by 1992 they had reached levels comparable to those of their peak during the late 1970s and early 1980s (U.S. Federal Bureau of Investigation, 1993, pp. 14,58; U.S. Bureau of Justice Statistics 1994, p. 13). Rates of overall firearm violence increased 24% between 1980 and 1992 (U.S. Bureau of Justice Statistics 1994, p. 13). These developments reignited public concern over firearm violence.

Heightened concern over firearm violence has drawn more attention to the types of firearms employed by offenders. A number of media and scholarly sources have suggested that criminals are making greater use of semiautomatic firearms (which allow a more rapid rate of fire and generally hold more ammunition than do non-semiautomatics) and high powered firearms (e.g., large caliber handguns and centerfire rifles). Though there is evidence that some firearms are more lethal than others (e.g., DiMaio 1985), very few studies have examined whether the prevalence of specific types of guns affect homicide rates. However, recent studies of gun homicides in Philadelphia (McGonigal et al. 1993) and Kansas City, Missouri (Koper 1995) and a study of gang homicides in Chicago (Block and Block 1993) have suggested that criminals' growing use of semiautomatic and/or high-powered firearms contributed to increases in homicide which occurred in these locations during the late 1980s and early 1990s.

We investigate this issue utilizing data from the city of Dallas, Texas for the period 1980 through 1992. The city of Dallas has a population of over one million and had one of the highest homicide rates in the nation during the early 1990s among cities with populations of 250,000 or more (Maguire et al. 1993, p. 372). Like many cities around the country, Dallas experienced generally rising levels of total and firearm homicides during the latter 1980s and early 1990s (see Chapter 4). The city's homicide rate per 100,000 dropped from approximately 35 in 1980 to 29 in 1983, but then rebounded in the mid-1980s, reaching 50 in 1991 before declining to about 40 in 1992. The rate of gun homicides per 100,000 followed the same general pattern; in 1990 and 1991 the rate was approximately double that of some years in the early 1980s. Firearm homicides accounted for 62% or more of total homicides during each year of this period, and by the early 1990s, they constituted 80% or more of Dallas' homicides. In addition, Fingerhut et al. (1992, p. 3058) reported that the firearm homicide rate per 100,000 for black males in Dallas County rose from 34.6 in the 1983-1985 period to 90.2 in the 1987-1990 period - one of the greatest increases in the country among 80 counties having at least 10,000 black males ages 15 to 19.

Using firearms confiscated by police as indicators of the types of guns circulating among criminal/high risk groups, we examine changes over time in Dallas' street gun arsenal and assess what impact, if any, these changes had upon gun violence mortality in

Dallas. We also examine whether trends in the use of different types of guns predict gun homicides better than does a more traditional measure of overall gun density. In so doing, we assess the relative contributions of more guns (gun density) and more lethal guns (gun type density) to homicide trends in Dallas. In this manner, the study attempts to enhance our understanding of how trends in the development, application, and distribution of weaponry technology have affected firearm homicides in Dallas and, presumably, elsewhere.

Chapter Two of this report reviews the literature on differential firearm lethality, changes in the crime gun arsenal, and the consequences of these changes. Chapter Three discusses the data and measures used for the study. Chapter Four examines Dallas' trends in gun crime, gun availability, and confiscations of specific types of guns. Chapter Five then presents the results of time series analyses relating weaponry trends in Dallas to gun homicides and the fraction of gun attacks resulting in death. Finally, Chapter Six presents a summary of the results and a discussion of their implications for research and policy. (A list of important firearm terms is presented in Appendix A).

2. DIFFERENTIAL FIREARM LETHALITY, CHANGES IN THE CRIME GUN ARSENAL, AND THE CONSEQUENCES FOR GUN VIOLENCE: EXAMINING A DIFFERENT DIMENSION OF THE GUN VIOLENCE PROBLEM.

2.A. The Comparative Lethality of Different Types of Firearms

Instrumentality, or the objective dangerousness pattern (Zimring 1972), is a term used to describe the deadliness of a weapon and the influence which this property has upon the outcome of an attack perpetrated with that weapon (also see Cook 1991). Alternatively, we may refer to this property as a weapon's lethality. There has been relatively little criminological research on the lethality of different types of guns relative to one another. Nevertheless, there are empirical and theoretical grounds for the claim that, holding other factors constant (such as shooter intent or skill), some guns are more lethal than others. Critical factors determining lethality include wounding potential (often referred to as stopping power), rate of fire, and ammunition capacity.

2.A.1. Stopping Power (Wounding Potential). The ability of firearms with larger calibers and higher velocities to inflict more serious wounds is well established in medical, forensics, and criminological literature (e.g., DiMaio 1985; DiMaio et al. 1974, 1975; Dobbyn et al. 1975; Hollerman 1988; Kleck 1984a; MacPherson 1992; also see review in Koper 1995, pp. 20-30). Although wounding effects are complicated further by factors such as ammunition shape and jacketing, we can roughly categorize shotguns and centerfire (i.e., high velocity) rifles as the most lethal firearms, followed by large caliber magnum handguns (e.g., .44 and .357 magnums), other large caliber handguns (e.g., .38, 9mm, and .45 calibers), and small caliber magnum handguns (e.g., .32 and .22 magnums). The least lethal firearms are rimfire (i.e., low velocity) rifles and small caliber, non-magnum handguns (e.g., .22 and .25 calibers). At perhaps the most general level, we can classify shotguns, centerfire rifles, and large caliber handguns (i.e., those greater than .32 caliber) as more lethal guns and small caliber handguns and rimfire rifles as less lethal guns.

Evidence for the greater lethality of criminal attacks with large and small caliber guns is provided by Zimring's (1972) study of a sample of fatal and non-fatal firearm attacks which took place in Chicago during 1970. Zimring's crosstabulations of attacks by gun caliber and wound location for both single and multiple wound incidents yielded evidence that attacks with larger caliber guns are more likely to result in death. Focusing on lethality differences between .22 caliber and .38 caliber guns, Zimring (1972, p. 106) estimated that gun attack fatalities would have been 62% higher if all gun assailants had used .38's and 48% lower if all gun assailants had employed .22's. These estimates should be treated with some caution, however, because Zimring could employ only crude controls for offender, victim, and situational characteristics which may have influenced the outcomes of these attacks.

In particular, there is the possibility that the apparent relationship between use of large caliber handguns and gun homicide is due in part to an association between offender characteristics and weapon selection. Wright and Rossi's (1986, p. 171) survey of incarcerated felons in ten states produced some evidence that serious offenders, as a group, tend to own larger caliber handguns than does the general population (for a contrary finding, see Burr 1977, cited in Wright et al. 1983, pp. 183-187). On the other hand, it is not clear that the most dangerous of these offenders possessed the most lethal guns. The most serious gun offenders preferred more powerful handguns, but the correlations between the felons' most preferred handgun characteristics and those of their most recently owned handguns were rather modest (pp. 174-175). Moreover, the average criminality score (based on the number and the seriousness of the felons' self-reported offenses) was lower for offenders who had primarily used shotguns (the most deadly firearms at close range) than for offenders who had primarily used handguns (p. 75). Finally, gun criminals in this sample usually owned several guns, and it is not clear which guns they used in crime (pp. 80,173). When asked about their motives for acquiring their most recent handguns, the correlation between the felons' preferences for traits like large caliber and a crime use motive was only 0.12 (p. 168). Wright and Rossi's results suggest that the weaponry possessed by criminals is strongly related to the types of guns in circulation and the resources (money, connections, theft opportunities) available to offenders; it is not solely determined by the violent propensities of offenders.

Thus, while the link between offender characteristics and use of more powerful guns is somewhat unclear, medical and forensics evidence provides ample reason to believe that differential firearm stopping power is a key factor explaining Zimring's results.

2.A.2. Rate of Fire and Ammunition Capacity (Semiautomatic Weaponry). Semiautomatic firearms (often referred to as autoloaders) fire once for every squeeze of the trigger, as do other firearms which are not fully automatic.[1] However, the firing mechanism of a semiautomatic loads a new round and recocks the gun for firing automatically after each shot, thereby facilitating a somewhat faster rate of fire relative to non-semiautomatics. Further, semiautomatics often have larger ammunition capacities than do their non-semiautomatic counterparts. Whereas revolvers commonly hold 5 to 9 cartridges, ammunition magazines for semiautomatic pistols commonly hold 5 to 17 cartridges (Kleck 1991, p. 66; also see Fjestad 1996; Quertermous and Quertermous 1993; Warner 1995). Some semiautomatic rifles and handguns can accept magazines with as many as 30 or more bullets.[2]

Thus, semiautomatic firearms would seem to be more lethal than non-semiautomatics; semiautomatics permit more rapid firing, and they often have larger ammunition capacities. However, a disadvantage to these weapons is that they can jam during firing, a problem which is undoubtedly more severe for cheaper guns. As of yet, there have been no studies comparing the fatality rates of attacks with semiautomatics and non-semiautomatics, and there is little evidence on the direct roles of firing rate and ammunition capacity in gun attacks. An examination of recovered handguns used in Philadelphia homicides during 1990 revealed that the average number of shots fired in these incidents was 2.1 for cases involving revolvers and 2.7 for cases

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[1]Fully automatic firearms have the most rapid rate of fire, shooting continuously as long as the trigger is held down. These guns have been illegal to own in the U.S. without a special permit since 1934 and are rarely used in crime (Kleck 1991, p. 67).

[2]Title XI of the federal government's Violent Crime Control and Law Enforcement Act of 1994 prohibits the manufacture, possession, and sale of most ammunition feeding devices capable of holding more than 10 rounds. However, ammunition magazines manufactured prior to the enactment of this legislation in September 1994 are exempt.

involving semiautomatics (McGonigal et al. 1993, p. 534). The faster firing rate of semiautomatics could have been responsible for some of this shot differential.[3] This difference amounts to only about one bullet per homicide, but such a shot differential (if applicable to gun attacks in general) could increase the proportion of gun assaults which prove fatal as semiautomatics become more prevalent in crime.

In terms of ammunition capacity, there is some evidence suggesting that homicide victims killed with semiautomatic weapons equipped with large capacity magazines (i.e., magazines holding more than 10 rounds) tend to receive more gunshot wounds than do victims killed with firearms having lower ammunition capacities (Roth and Koper 1997). On the other hand, the available evidence also suggests that most criminal gun attacks involve three or fewer shots (Kleck 1991; McGonigal et al. 1993; also see Roth and Koper 1997), a number well within the ammunition capacity of non-semiautomatic weapons.

Overall, the evidence for an instrumentality effect attributable to the firing rate and ammunition capacities of semiautomatics is limited and equivocal. Yet in the absence of any substantial data on the dynamics of criminal shootings, it seems plausible that the ability to fire more times and at a faster rate gives attackers using semiautomatics a greater probability of hitting their targets at least once during an attack.

2.A.3. Overall Lethality. Hence, there are a number of gun

[3]Changes in offender behavior must have also played a role; the same study revealed that in 1985 semiautomatic cases averaged only 1.6 shots, while revolver cases averaged 1.9 shots. It is not clear to what extent the increase from 1985 to 1990 in shots fired for semiautomatic cases was due to changes in offender behavior and/or changes in the quality of semiautomatic weaponry.

characteristics making certain types of firearms demonstrably or theoretically more lethal than others. High velocity projectiles, large calibers, semiautomatic firing mechanisms, and large ammunition capacities, alone or in combination, enhance gun lethality. Nonetheless, there is little empirical evidence regarding the effects of these gun characteristics on the lethality of gun attacks.

2.B. Trends in Criminal Weaponry and Lethal Violence

The preceding discussion suggests that changes in the availability of differentially lethal guns among criminal/high risk groups may affect rates of gun homicide. This hypothesis is consistent with inferences drawn from studies of gun density and homicide. The literature on gun availability and homicide is plagued by methodological weaknesses and conflicting findings and is not reviewed here (for reviews, see Cook 1991; Kleck 1991; Wright et al. 1983). But to the extent that gun density is related to homicide, its effect seems to work through the level of gun density among criminal/high risk groups. A number of studies indicating that gun density has positive effects on homicide, including a number of the more methodologically sound gun density studies (e.g., McDowall 1991), utilized gun density measures reflecting criminal gun use (e.g., the proportion of robberies and suicides involving guns) or found effects operating indirectly through robbery (Cook 1979; Kleck 1984b). This conclusion is also supported indirectly by evidence of homicide reductions stemming from gun control interventions aimed at urban, higher risk populations (Loftin et al. 1991) and gun enforcement efforts directed at criminals (Zimring 1975). Thus, it seems that measures of gun availability among criminal/high risk groups are helpful in predicting and explaining homicide trends. An extension of this idea is to examine the specific types of firearms circulating among these groups. Throughout this report, we use the term aggregate gun lethality to refer to the aggregate characteristics of the crime gun arsenal measured in terms of stopping power, rate of fire, and/or ammunition capacity.

2.B.1. Trends in Crime Guns Examination of data from both official sources (U.S. Bureau of Alcohol, Tobacco, and Firearms 1976; 1977; Block and Block 1993; Brill 1977; Cox Newspapers 1989; Hutson et al. 1994; Kleck 1991; Koper 1995; Little and Boylen 1990; McGonigal et al. 1993; Criminal Justice Research Center, Virginia Department of Criminal Justice 1994; Zawitz 1995; also see review in Wright et al. 1983) and self report sources (Burr 1977, cited in Wright et al. 1983; Sheley and Wright 1993; Wright and Rossi 1986; U.S. Bureau of Justice Statistics 1993) collected at various points in time indicate that there have been increases in the lethality of criminal weaponry in recent years (for a review, see Koper 1995, pp. 67-102). Most of these changes have involved handguns. Overall, the major discernible trend has been an increase in the use of semiautomatic weaponry. In one of the few longitudinal studies available, Koper (1995, p. 197) found that semiautomatics increased from 29% of handguns confiscated by Kansas City, Missouri police in 1985 to 54% in 1993. This is not surprising; offenders tend to use recently manufactured guns (Zimring 1976), and production of semiautomatics grew from 28% of domestic handgun production in 1973 to 80% in 1993 (Zawitz 1995, p. 3).

In addition, available data suggest there has been an increase in the use of large caliber handguns. Koper (1995, p. 196), for example, found that large caliber handguns (defined as handguns having calibers larger than .32) accounted for 54% of confiscated handguns in Kansas City in 1985 and 63% in 1993. By comparison, Brill (1977) reported that large caliber handguns accounted for 45% of confiscated handguns on average among seven cities which he studied during the 1970s. Moreover, large caliber handguns represented only 39% of the handguns confiscated in Kansas City during the mid-1970s (U.S. Bureau of Alcohol, Tobacco, and Firearms 1976), suggesting that there has been a substantial rise in criminal use of large caliber handguns in Kansas City, and presumably elsewhere, since that time.

This trend also seems to have been driven by manufacturing and sales trends in the general civilian gun market. The Bureau of Alcohol, Tobacco, and Firearms (BATF) does not publish national handgun production totals by caliber, but figures available for individual gun manufacturers show that a number of companies increased their production of large caliber handguns relative to small caliber handguns during the late 1980s and early 1990s. To illustrate, large caliber handguns produced by Sturm Ruger, one of the nation's largest handgun manufacturers, rose from 45% of the company's handgun production in 1986 to a peak of 85% in 1991 (Violence Policy Center 1995, p. 21). Further, a number of firearm companies making inexpensive handguns commonly used in crime accelerated their production of large caliber handguns during this period. Davis Industries, for example, boosted large caliber handgun production from 19% of its production in 1989 to nearly 60% in 1991 and 1992 (Violence Policy Center 1995, p. 27; also see Wintemute 1994a, pp. 15-17). By 1994, large caliber handguns represented about 61% of privately owned handguns according to national survey estimates (Cook and Ludwig 1996,

p. 17).

Finally, there has also been a substantial rise in the use of firearms combining high stopping power and semiautomatic firing. Zawitz (1995, p. 3) reported that production of large caliber semiautomatic handguns began to increase notably beginning in 1987. From 1991 to 1993, .380 and 9mm caliber pistols were the most frequently manufactured handguns in the U.S., together accounting for 39% of domestic handgun production. This change has also become evident in the composition of crime guns. In Kansas City, large caliber semiautomatic handguns increased from approximately 10% of confiscated handguns in the mid-1980s to over 30% by 1992 (Koper 1995, p. 198).

2.B.2. Have Increases in Aggregate Gun Lethality Increased Homicides? Recent studies of firearm homicides in Philadelphia (McGonigal et al. 1993) and gang-related homicides in Chicago (Block and Block 1993) have suggested that growth in the use of semiautomatics and large caliber handguns by criminals contributed to increases in firearm homicides in those cities. To illustrate, Block and Block (1993) have argued that a 100% rise in Chicago gang homicides from 1987 to 1990 was due largely to an increase in the use of semiautomatic and large caliber handguns by gang members. The percentage of gang murders committed with semiautomatic weapons rose from 22% in 1987 to 31% in 1990 and accounted for 39% of the growth in gang homicides (1993, p. 7). Likewise, gang murders committed with large caliber guns (defined in that study as guns .38 caliber or greater) went from 26% in 1987 to almost 39% in 1990, representing 51% of the growth in gang homicides.

McGonigal et al. (1993) examined Philadelphia firearm homicides which occurred in 1985 and 1990 and collected information regarding the characteristics of the victims and, where possible, the weapons involved. Firearm homicides numbered 145 in 1985 and 324 in 1990, representing a 123% increase over the five year period. The weapon analysis focused on handguns, which accounted for 90% or more of the homicide guns in both years. Weapon identifications were made for 70% of the handguns used in murders in 1985 and 66% of those used in 1990. Like the Blocks, McGonigal et al. found a shift towards semiautomatic weaponry and large caliber guns among homicide cases (1993, p. 533). The percentage of identified handguns which were semiautomatics rose from 24% in 1985 to almost 39% in 1990. Large caliber handguns (which we define as those greater than .32 caliber) accounted for 53% of the guns in 1985 and 68% in 1990 (calculated from table 3, p. 533). Finally, large caliber semiautomatic handguns went from 5.5% of the handguns in 1985 to almost 33% in 1990.

Along similar lines, Webster et al. (1992) reported that the mean number of wounds suffered by gunshot victims admitted to a trauma center in Washington, DC increased from 1.44 before 1987 to 2.04 for the 1988 to 1990 period, a shift which reversed a previous downward trend in gunshot patient mortality.[4] Webster et al. also noted that police data showed a 51% increase in the ratio of gun homicides to gun assaults from 1983 through 1990, a trend suggesting that gun attacks in Washington had become more lethal (p. 697). Webster et al. attributed these findings in part to the growth in the use of semiautomatic weapons. Citing police figures, they observed that the

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[4]They also showed that there were statistically significant increases in the percentage of gunshot victims with two or more wounds and five or more wounds (1992, p. 696).

number of semiautomatic pistols confiscated by police doubled from 1987 to 1990, and that the ratio of confiscated revolvers to semiautomatic handguns declined from 2 to 1 in 1987 to 0.79 to 1 by 1991 (p. 698). Firearm homicides increased substantially in Washington, DC during the late 1980s; thus, Webster's et al.'s findings could be interpreted as support for an aggregate gun lethality effect attributable to semiautomatics, although Webster et al. acknowledge that changes in offender behavior may have played a role in causing the observed gunshot trends (p. 698).

The results of these studies are intriguing, but their meaning is open to debate. None of the three studies was able to show whether the fatality rates of attacks with semiautomatics and large caliber handguns were higher than those for other gun attacks, or whether the gun types in question were disproportionately involved in homicides and/or multiple wound cases relative to their use in non-fatal and/or single wound gun assaults. In addition, the Chicago and Philadelphia studies did not provide evidence regarding trends in the fatality rate of gun attacks.

Moreover, these studies did not account for other correlates or trends in violence and homicide. There was a dramatic increase in officially-recorded firearm violence and weapons violations, particularly among juveniles, during the late 1980s and early 1990s (Federal Bureau of Investigation 1993; Maguire et al. 1993). Gang-related and drug-related violence increased in many cities during this period and undoubtedly played a role in the rise of firearm homicides, particularly among inner city young males (Block and Block 1993; Goldstein et al. 1989; Johnson et al. 1990; Reiss and Roth 1993; Spergel 1990). Furthermore, the spread of violent alternative cultures (Reiss and Roth 1993) may have led to an increase in the proportion of gun attacks in which offenders had a sustained intent to kill. It is possible that this wave of firearm violence coincided with a change in available weaponry, and that the latter had little or no effect on homicide trends.

In a precursor study to this one, Koper (1995) employed time series methods to examine trends in fatal gun violence and the types of guns confiscated by police in Kansas City, Missouri for the period 1985 through 1993. Using bimonthly and quarterly confiscations as aggregate indicators of guns used in violence, Koper created measures for the percentages of total guns and handguns with higher stopping power, semiautomatic firing mechanisms, and the combination of higher stopping power and semiautomatic firing mechanisms. His investigation revealed that trends in the use of guns with higher stopping power (i.e., shotguns, centerfire rifles, and, especially, large caliber handguns) had a statistically significant influence on trends in gun and total homicide. Focusing on large caliber handguns, for example, Koper's results indicated that a one percent (absolute) increase in the percentage of confiscated handguns with a large caliber was associated with one additional homicide per quarterly period.

Trends in the relative use of semiautomatics, in contrast, did not have clear relationships to gun homicides after controlling for preexisting trends in gun homicides. Interestingly, a gun density indicator, defined as the proportion of robberies perpetrated with guns, also had no clear relationship to gun homicides, suggesting that in some contexts the density of more lethal guns (measured in terms of stopping power) exerts more influence on gun homicides than does overall gun density.

Thus, there is limited evidence to support the notion that changes in the crime gun arsenal have contributed to recent trends in firearm homicides. Overall, the evidence from medical, forensics, and criminological sources is consistent with the premises that some guns are more lethal than others and that changes in the types of guns used by offenders can influence the lethality of gun violence independently of other factors. The combined evidence is strongest for instrumentality effects attributable to larger caliber, higher velocity firearms.[5]

[5]The issues presented in this chapter are reviewed in more detail in Koper (1995).

3. DATA AND MEASURES

Using data from Dallas, Texas for the period 1980 through 1992, this study investigates changes over time in Dallas' crime weapon arsenal (both in terms of gun lethality and gun density) and utilizes statistical time series methods to determine whether these trends affected gun violence mortality in Dallas.

3.A. The Dallas Gun Data

The study is based on information regarding approximately 58,000 guns confiscated by Dallas police from 1980 through 1992. The data include guns seized in association with arrests or other incidents as well as guns which were found or voluntarily turned in by citizens.

These data were obtained from a master gun property file provided by the Property/Auto Pound Section of the Dallas Police Department. Guns confiscated by Dallas police are kept in a secure facility at the department's central headquarters and are not released except for lab testing, court cases, or disposal (e.g., destruction or return to owner). The handling and disposition of confiscated firearms are guided by written operating procedures and policies.

Officers in the Property Section maintain a computerized inventory database which includes, among other items, the caliber (or gauge) of the firearm, an NCIC (U.S. Federal Bureau of Investigation National Crime Information Center) code corresponding to the firearm's type (e.g., revolver, semiautomatic pistol, pump-action rifle, etc.), and the date on which the firearm was confiscated. Other potentially useful information, such as firearm make and model and offense type, were missing for most of the records and/or were not maintained consistently throughout the study period. Consequently, all confiscated firearms were analyzed and characterized according to basic weapon type and caliber groupings. Less than 1% of the records in the master file had missing weapon type or caliber fields, and preliminary work with the data suggested that they had very low rates of error with respect to the designation and recording of these basic firearm characteristics (see Appendix B).

Dates of confiscation, in contrast, were missing from the majority of the pre-1988 records. By aggregating the gun data into bimonthly and quarterly time series databases, however, it was possible to estimate the bimonthly and quarterly periods of confiscation for most of the 1980-1992 records.[6] Bimonthly confiscation dates could not be estimated for approximately 15% of the records for 1980. For the years 1981-1983, an estimated 5% to 10% of the records could not be accurately dated on a bimonthly basis. This figure dropped to 2% to 3% for 1984 and 1985 and was 1% or less for subsequent years. Missing rates were lower for the quarterly data file. Records which could not be assigned to bimonthly or quarterly periods were dropped from the analysis. However, the focus of this investigation is on the characteristics of the guns rather than their numbers, and there is no reason to believe that the guns excluded from the analysis due to missing date information differed systematically from the other guns.[7]

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[6]This was done using available dates and service incident numbers. More details are provided in Appendix B. The original study design proposed to use gun data spanning back to 1978. However, the 1978 and 1979 data were too problematic for analysis (see Appendix B).

[7]A cautionary note is that there were unusually low numbers of guns appearing in the master data file for certain months of the spring and summer of 1982 (see Appendix B for more details). The author consulted personnel in the Dallas Police Department but was unable to reach a definitive conclusion as to whether this drop represented a true reduction in firearm confiscations or missing

3.B. Measuring the Criminal Arsenal: Methodological Issues

There are a number of limitations to using guns confiscated by police as indicators of guns used in violence. Not all confiscated guns are associated with violent crime and not all guns used in violent crime are seized by police. Available data (much of which is from the 1970s and may be outdated) suggest that approximately 20%-25% of confiscated guns are seized in association with violent offenses or shots fired incidents (U.S. Bureau of Alcohol, Tobacco, and Firearms 1977; Brill 1977; Shaw 1994). The majority of guns seized by police are connected to illegal possession or carrying charges, and perhaps 20% to 25% are found by police or voluntarily turned in by citizens (Brill 1977). Finally, it is common for officers to seize guns for "safekeeping" in contexts, such as domestic disputes, in which a serious crime has not occurred but officers are concerned the gun may be used in crime (Shaw 1994).

By the same token, changes over time in clearance rates for gun crimes or other changes in police or legal policy may create fluctuations in the fraction of confiscated guns seized in association with violent crimes, thus introducing another potential biasing factor in using all confiscated guns as indicators of guns used in violence.[8] For example, drug enforcement activity increased in many cities around

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records from the master property file. Assuming that the drop represents a record-keeping problem (such as records being mistakenly deleted from the file), there is no reason to believe that the missing guns differed systematically (with respect to gun type and caliber) from those present in the master file. Furthermore, the graphs of the gun series in figures 1-6 provide no evidence of outliers attributable to the affected data points.

[8]To illustrate, the clearance rate for gun assaults in Dallas dropped from 69% in 1980 to 48% in 1992 (calculated from UCR Return A data tapes). On the other hand, the clearance rate for gun robberies was approximately 25% in both of these years.

the nation during the late 1980s, from which we can infer that guns seized in association with drug arrests rose as a fraction of gun seizures.[9]

Nevertheless, firearms used in violent crime (i.e., murders aggravated assaults, and robberies) do not appear to be more lethal in terms of caliber and firing action than do other confiscated firearms, the bulk of which are connected to weapons and narcotics violations. Indeed, the two groups of weapons appear to be quite similar (Brill 1977; U.S. Bureau of Alcohol, Tobacco, and Firearms 1977). One exception is that large caliber handguns are somewhat more common among murder guns, but murder guns represent a small percentage of all confiscated guns.[10]

Moreover, the fact that a seized gun is not known to have been used in a violent crime does not rule out the possibility that it had been used or would have been used in violent crime. Substantial percentages of adult and juvenile offenders carry firearms on a regular basis for protection and to be prepared for criminal opportunities (Sheley and Wright 1993; Wright and Rossi 1986). In Kansas City, Missouri, for example, about 60% of the guns seized as a result of regular police enforcement activity in high crime beats in 1992 were seized in conjunction with pedestrian checks, car checks,

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[9]Personnel in Dallas indicated to the author that guns seized in drug raids rose substantially in that city during the late 1980s and early 1990s, though quantifiable data on this trend are not available. However, there were no other major legal or policy changes in Dallas which influenced gun enforcement activity during the study period.

[10]Semiautomatics were actually somewhat less prevalent among violent crime handguns than among other crime handguns in three cities studied by the U.S. Bureau of Alcohol, Tobacco, and Firearms during the 1970s (1977, pp. 96-98). However, the use of semiautomatics has grown dramatically since that time, so that generalization may no longer apply.

and other traffic violations (Shaw 1994, p. 263).[11] In addition, many confiscated guns are taken from persons involved in drugs (Brill 1977; Shaw 1994) - i.e., persons involved disproportionately in violence and illegal gun traffic (National Institute of Justice 1995; Sheley and Wright 1993). It also seems plausible that discarded guns found by patrol officers were formerly possessed by criminal or high risk persons, including some who may have been fleeing from crime scenes.

Despite their limitations, confiscated guns are a reasonable index of guns used in violent crime, and they are the best available indicator of changes over time in the types of guns used in crime and possessed and/or carried by criminal and otherwise deviant or high risk persons.

3.C. Aggregate Gun Lethality Measures

Based on the discussion of differential firearm lethality in Chapter Two, the confiscated firearms were grouped into basic categories based on stopping power (i.e., wounding potential), rate of fire, and ammunition capacity. The following measures were created for each bimonthly and quarterly period.

1) Weapons with high stopping power (**large guns**): the percentage of guns which were large caliber handguns (i.e., greater than .32 caliber), centerfire rifles (approximated by all rifles having other than .22 caliber), or shotguns. The classification of handguns into general small and large caliber groupings based on a dividing point of .32 caliber is based on convention in the firearms literature (U.S. Bureau of Alcohol,

[11] This calculation excludes guns seized by special crime hot spots patrols which were proactively targeting guns. Thus, the figure reflects normal police activity.

Tobacco, and Firearms 1976; 1977) and assessments of handgun stopping power (DiMaio 1985; Kleck 1984a).[12] With respect to rifles, the data do not have enough detail to distinguish .22 caliber rimfire (low velocity) rifles from .22 caliber centerfire (high velocity) rifles. Since the majority of .22 caliber rifles and ammunition on the market are rimfires (e.g., see Warner

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[12]A basic large/small gun measure was also used to avoid complexities and imprecision in the use of other potential lethality measures. The severity of a gunshot wound depends on a complex host of factors: the kinetic energy of the bullet (which is based on its mass and velocity); the bullet's caliber, shape, and construction; the bullet's angle of yaw; and the types of tissue struck by the bullet (DiMaio 1985, pp. 41-49; Fackler 1996). When assessing the comparative performance of different handguns and ammunition, some sources stress a bullet's kinetic energy when fired (e.g., DiMaio 1985, p. 140; Warner 1995, p. 223). Others (e.g., Wintemute 1996; Kleck 1984a) stress a more sophisticated measure called relative stopping power (RSP) which is based on a bullet's kinetic energy, cross-sectional area, shape, and material. (More complex assessments involve firing ammunition into gelatin blocks designed to simulate human tissue in order to measure kinetic energy delivered to the target [e.g., DiMaio et al. 1974; but see MacPherson 1996] or to measure bullet penetration and expansion [e.g., Dahlstrom and Powley 1996]).

Using common measures like RSP or kinetic energy is complicated by the fact that they can vary substantially for different bullets of the same caliber, and data regarding ammunition characteristics were not available for this study. It is also useful to note that lethality does not necessarily increase in a linear fashion with bullet caliber. For example, whether measuring RSP or kinetic energy, the lethality of 9mm ammunition (which is approximately .35 caliber in inches)is typically greater than that of .38 caliber ammunition (e.g., see Wintemute 1996, p. 1751; DiMaio 1985, p. 140; Warner 1995, p. 223). Similarly, .357 magnums have lethality comparable to or greater than that of .45 caliber handguns. (Also see ammunition comparisons in DiMaio et al. 1974). For these reasons, the average caliber over time was not employed as a lethality measure.

A limitation to the percentage large gun measure used in this study, however, is that it masks the distribution of calibers within the broad groupings. For comparative purposes, therefore, RSP values presented in Wintemute (1996, p. 1751) for common handgun calibers and ammunition brands were used to compare changes in the average RSP of confiscated handguns and the percentage of handguns having large calibers. Both measures increased 36% from 1980 to 1992, thus lending support to the validity of the large/small gun measure for handguns. The measure could be more problematic for measures combining long guns and handguns; nevertheless, handguns represent a large majority of crime guns and drove most of the changes in Dallas' crime gun arsenal.

1995), all .22's in these data were counted as rimfires.

2) Semiautomatic weaponry (**semis**): the percentage of all guns which had a semiautomatic firing mechanism.

3) Weapons combining high stopping power and a semiautomatic firing mechanism (**large semis**): the percentage of all guns having both high stopping power (as defined in measure 1) and a semiautomatic firing mechanism.

Since most firearm crime is perpetrated with handguns, we also computed measures corresponding to handguns only.

4) Handguns with high stopping power (**large handguns**): the percentage of handguns with a caliber larger than .32 caliber.

5) Semiautomatic handguns (**semi handguns**): the percentage of handguns having a semiautomatic firing mechanism.

6) Handguns combining high stopping power and semiautomatic firing (**large semi handguns**): the percentage of handguns having a caliber larger than .32 and a semiautomatic firing mechanism.

Due to limitations of the data, it was not possible to take into account other potentially important factors such as ammunition shape and jacketing, exact ammunition capacity, or barrel length. Nonetheless, the indexes capture important general distinctions between groups of firearms.[13] [14]

3.D. Violence Measures

A number of violence measures were obtained from the FBI's Supplemental Homicide Reports (SHR) and Uniform Crime Reports (UCR) Return A tapes: total homicides, gun homicides, firearm aggravated assaults, total robberies, and gun robberies. These measures were aggregated at bimonthly and quarterly levels. Justifiable homicides and negligent manslaughters were excluded from the homicide data.

The primary outcome measures are **gun homicides** and the percentage of gun assaults resulting in death (**fatality rate of gun attacks**). The latter measure is defined as 100 times gun homicides divided by the sum of gun aggravated assaults and gun homicides. Though some of the gun lethality measures are based on only handguns, the outcome measures are based on all guns crimes because estimates of handgun assaults are not available, and because the exact type of firearm is

[13]Data limitations made it impossible to consider ammunition characteristics. With respect to ammunition capacity, the semiautomatics should in general have greater ammunition capacities than the non-semiautomatics. As discussed in Chapter 2, however, the number of shots fired in most criminal incidents is small. Therefore, any difference in the lethality of attacks with semiautomatic handguns and revolvers may be due to the former group's greater firing rate rather than their ammunition capacities. In terms of barrel length, forensics literature suggests that the most important distinction in barrel length is between handguns (relatively low velocity firearms) and centerfire long guns (high velocity firearms); it is not clear than handgun barrel length creates an appreciable difference in wound severity.

[14]These measures capture changes in the composition of the crime gun arsenal over time. We did not use raw numbers of confiscated guns because police behavior (e.g., intensified narcotics enforcement) can have a substantial impact on the number of guns seized at a given point in time independently of gun crime levels. In addition, data limitations discussed in this chapter and Appendix B made it impossible to collect complete information on all firearms confiscated during the study period.

not known in a notable proportion of homicide cases.[15] Nevertheless, a large majority of gun crimes are committed with handguns - indeed, some studies indicate that 90% or more of gun homicides are committed with firearms (Hargarten et al. 1996; McGonigal et al. 1993) - so the results of these analyses should be informative.

A limitation to the fatality rate measure is that UCR data on firearm assaults do not indicate whether the gun was fired or whether the victim suffered a gunshot injury. Yet the hypothesized instrumentality effects attributable to semiautomatics are contingent on offenders firing their guns, and the instrumentality effects of guns with high stopping power are contingent on victims being wounded. Ideally, therefore, one would want to have measures of gun attacks resulting in discharges and those resulting in one or more gunshot wounds.[16] In the absence of such figures, the available data were employed to approximate the fatality rate of gun attacks.

Using all gun aggravated assaults, the yearly fatality rate in these data ranged from 6% to 10%. In contrast, more refined estimates suggest that approximately 15% of gunshot wound cases known to police result in death (Cook 1985, pp. 94-96; also see Koper 1995, p. 176). National-level estimates from medical sources suggest that the fatality rate for gunshot victims in assaultive cases may be as high as 25% (Annest et al. 1996). The author is not aware of any data providing fatality rate estimates for all gun discharge cases.

An additional problem with the fatality rate variable is that

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[15]For example, nearly a third of the gun homicides which occurred in Dallas from 1980 to 1990 involved unspecified firearm types according to the SHR.

[16]Based on data from one city, Cook (1985) estimated that victims are shot in 48% of gun aggravated assaults recorded by police.

improvements in the recording of non-fatal crimes by police appear to have caused a rise in officially-reported non-fatal violent crime at the national level during the last two decades (e.g., O'Brien 1996). Consequently, the denominator of the fatality rate measure is likely to have been influenced by trends in police reporting. Chapter Five discusses procedures which were utilized to compensate for this factor.

A measure of **gun density** among criminal/high risk groups, defined here as the percentage of robbery incidents involving guns, was also derived from UCR data. This variable provides an index of changes over time in the availability and use of guns relative to that of other weapons. The gun density measure was used to predict gun homicides, and its performance was compared to that of the gun lethality measures in order to determine whether gun density or gun lethality is a better predictor of gun homicides. The validity of gun robberies as a gun density measure has been demonstrated in other research (Cook 1979; McDowall 1991).[17] Finally, in some of the analyses, gun robberies (**grobs**) and total robberies (**robs**) were employed as covariates to control for trends in gun violence and total violence, respectively.

[17]Similar types of gun density indexes employed in other studies have used a gun crime variable, such as this one, combined with the proportion of suicides committed with guns (e.g., McDowall 1991). For this study, however, a gun density indicator corresponding more directly to variation in gun use in street crime seems more appropriate as an analog to gun lethality indexes based on guns confiscated by police.

4. TRENDS IN WEAPONRY AND GUN VIOLENCE

4.A. Trends in Gun Measures

Table 1 presents the approximate number of firearms confiscated by Dallas police during each year of the study period and shows the distribution of handguns, rifles, and shotguns among these weapons. In general, firearm confiscations were notably higher during the latter 1980s and early 1990s. Our concern, however, is with the characteristics of the weapons rather than their numbers. The handgun/long gun distribution remained quite stable throughout the period. Handguns predominated, accounting for 80% or more of the confiscated firearms in each year.

Tables 2 through 4 show that the lethality of Dallas' gun arsenal increased on all three dimensions of lethality discussed earlier, thus confirming inferences drawn from other literary sources (see Chapter 2). Bimonthly trends for the gun lethality variables defined in the previous chapter are shown in figures 1 through 6. Changes in the gun arsenal generally occurred at their fastest rates during the later years of the study period. Breakdowns of these figures by handguns and long guns indicate that these changes were driven primarily by changes in the handgun arsenal.

To illustrate, Table 2 shows that shotguns, high velocity rifles, and large caliber handguns accounted for around 50% of confiscated firearms during the early 1980s. By the early 1990s, however, they had increased to approximately 65% of confiscated weapons. Most of this increase was attributable to a rise in the use of large caliber handguns; such handguns rose from approximately 45% of confiscated handguns in the early 1980s to over 60% by the early 1990s.

Changes in the use of semiautomatics and large semiautomatics were even more dramatic (tables 3 and 4). Again, these changes were driven by changes in confiscated handguns. Semiautomatic handguns accounted for only about a quarter of confiscated handguns in 1980, but by 1992 they had risen to 65%, a relative increase of approximately 160%. The growth in semiautomatic handgun confiscations was particularly strong from 1989 to 1992. Likewise, large caliber semiautomatic handguns increased nearly fourfold, rising from under 10% of confiscated handguns in 1980 to 38% in 1992.

Tables 5 through 7 provide more illustration of the mix of handgun types and calibers over time. In the early years of the period, .38s and .22s were by far the most common calibers (table 5). The .38 is a large caliber, but the .22 is the smallest typical handgun caliber, and most .22 caliber handguns use low velocity ammunition. Over time, the mix of calibers became greater, and the weaponry became more potent overall. The .25 caliber had become the most common small caliber handgun by 1992, to some extent replacing the somewhat smaller .22s. Indeed, .22 calibers had dropped from nearly a third of confiscated handguns in 1980 to 14% by 1992. Among middle range calibers, there was some shift away from .32s and towards larger .380s.[18] Among larger calibers, .38s were still common in 1992, but there had been a notable shift towards the use of 9mm handguns (expressed in inches, 9mm bullets are approximately .35 caliber) which generally have higher velocities than do .38s (Warner 1995, p. 223).

Similar patterns are apparent in tables 6 and 7 which present the most common semiautomatic and non-semiautomatic calibers, respectively. Nearly half of the confiscated semiautomatic handguns

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[18]Bullets of .380 caliber are generally lighter than .38's (Warner 1995, p. 223). Consequently, they tend to be classified as a middle-range caliber.

in 1980 were small .25 caliber weapons. These guns dropped to about a third of semiautomatic handguns by 1992. Over half of the semiautomatic handguns confiscated in 1992 were .380 or 9mm firearms. In 1980, .22s and .38s each constituted over a third of the non-semiautomatic handguns (these were mostly revolvers, but they also included different varieties of derringers). By 1992, .22s had decreased to a quarter of the non-semiautomatics. In contrast, confiscations of .38s grew somewhat in relative terms as did confiscations of .357 magnums (one of the most lethal handguns). (Non-semiautomatics were shrinking as a percentage of all handgun confiscations, however, and .357s did not grow consistently as a percentage of all handguns).

4.B. Trends in Violence and Gun Density Measures

Table 8 presents yearly figures for the violence and gun density measures. Total and gun homicides declined somewhat in the early 1980s and then rose substantially through the late 1980s and into the early 1990s. In 1991, there were about twice as many gun homicides in Dallas as there were during most years of the early 1980s. In general, gun homicides were at their highest levels during the later years of the period when aggregate gun lethality was also at its highest. Throughout the period, gun homicides constituted the majority of homicides, but this pattern intensified during the latter years of the period.

Nonetheless, Dallas' gun homicide trends appear to have been driven largely by trends in overall gun crime. Gun assaults and gun robberies followed patterns similar to that of gun homicides. Gun robberies in 1991 were about twice as high in number as they had been during the early 1980s. The peak in gun assaults in 1991 represented a three-fold increase over the number of gun assaults committed during most years of the early and mid 1980s. The rise in gun assaults outpaced that of gun homicides, causing the fatality rate of gun attacks to decline from 9%-10% in the early years to 6% for the 1987-1992 period, a trend inconsistent with the gun lethality hypothesis.

Although gun violence increased, the percentage of robberies committed with guns did not change dramatically. Gun density decreased somewhat and reached its lowest point during the late 1980s before rebounding in the early 1990s. Yet the fraction of robberies involving guns was no greater in the early 1990s than it was during the early 1980s. The percentage of homicides committed with guns, in contrast, was at its highest during the early 1990s, perhaps suggesting that aggregate gun lethality was exerting more influence on gun homicide than was overall gun density.

Figures 7 through 11 illustrate bimonthly trends for the key violence measures utilized in the analysis, i.e., gun homicides, the fatality rate of gun attacks, gun density, gun robberies, and total robberies. Finally, figure 12 presents yearly changes in gun homicides, gun density, and selected handgun type variables relative to their 1980 levels. Gun homicides seem to track trends in the prevalence of large caliber handguns more closely than trends in gun density and the prevalence of semiautomatic handguns. At the same time, it appears that the variation in gun homicides is largely independent of trends in the gun measures. In the next chapter, we explore the relationships between aggregate gun lethality, gun density, and gun violence mortality using time series methods.

5. TIME SERIES ANALYSIS

Using regression with time series errors (Pankratz 1991; Pyndick and Rubinfeld 1991), bivariate and multivariate models were estimated to determine if aggregate measures of the lethality of confiscated firearms are related to gun homicides and the fraction of officially-recorded gun assaults resulting in death. Treating confiscated firearms as approximations of guns used in violence, we hypothesize that the lethality of guns confiscated at time t is related to the outcomes of violence at time t.

The basic models is:

$$Y_t = a + bX_{1t} + \ldots\ bX_{nt} + N_t$$

where Y_t is the dependent variable at time t, X_{1t} through X_{nt} are independent variables at time t, b_1 through b_n represent the contemporaneous effects of the independent variables on Y_t, and N_t is an error term. Because social phenomena tend to change slowly over time, a common problem in working with time series data is that the error term at time t tends to be correlated with its past values (t-1, t-2, etc.). This biases the standard errors and t statistics of the regression coefficients. Autoregressive, integrated, moving average (ARIMA) time series techniques were therefore used to construct the error components of these models. The ARIMA methodology provides a means of diagnosing and modeling time series processes. These processes represent ways in which the current value of a variable is related to its past values. (See Appendix C for a basic description of these processes).

When using regression with time series errors, the analyst regresses the outcome variable on the independent variable(s) and examines the correlations between the error terms at time t and its past values (t-1, t-2, etc.) by means of an autocorrelation function (ACF) (see Appendix C). Based on the observed pattern of correlations (if there are meaningful correlations), the analyst constructs an appropriate time series model to remove the correlation among the error terms. The model-building process is iterative, and the analyst may estimate and compare several models before arriving at a final one.[19]

By controlling for predictable patterns of variation over time in the dependent variable which are not explained by the independent variable(s), the methodology also provides some degree of control for unmeasured forces influencing the dependent variable continuously throughout the time period. This lessens, but does not eliminate, the chance of finding spurious relationships between the independent and

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[19]When constructing time series models with the ARIMA methodology, Pankratz (1991, p. 49) recommends special attention to any low lag autocorrelation coefficients which are 1.6 or more times their standard errors and any seasonal coefficients which are 1.25 or more times their standard errors. In practice, the author compared the autocorrelation coefficients to the value of $n^{-1/2}$, which is the asymptotic standard error of the autocorrelations of a white noise process (i.e., a process having no significant autocorrelation, see Granger and Newbold 1986, p. 99). In many instances, more than one time series process could be adequately fit to a given regression model. In some cases, moreover, the estimates and significance levels of the gun terms were sensitive to these model specifications. For this reason, the results should be treated cautiously. In arriving at the final models, the author considered the statistical adequacy of the autoregressive/moving average parameters, the adequacy of test statistics for remaining autocorrelation in the residuals, the parsimony of the model, and the model's goodness of fit, as measured by the residual standard error and Akaike's (1974) AIC criterion (see Appendix C).

Finally, note that tables 9 through 14 present Ljung-Box Q test statistics for residual autocorrelation calculated at the third seasonal lag. This corresponds roughly to the value of n/4 which is recommended as a guide in choosing the maximum value of ACF lags to examine (Pankratz 1991, p. 35). In general, the Q statistics were evaluated at lags 6, 12, 18, and 24 (the default values produced by SAS/ETS software). According to Granger and Newbold (1986, p. 99), the validity of the Q statistic rests on having at least 10 to 20 lags for its computation.

dependent variables.

Models were estimated at both bimonthly and quarterly time aggregations. Relative to the bimonthly models, the quarterly models have the advantage of larger samples of guns and homicides, but the disadvantage of a shorter time series.

The gun type and density measures were scaled as percentages. Thus, the regression coefficients represent the effects on the dependent variable which result from an absolute one percent increase in the gun measures. Raw numbers of gun homicides were used as an outcome variable rather than rates due to the facts that population counts tend to change slowly over time and that subyearly estimates of the city's population are unavailable. The models were estimated using maximum likelihood techniques available with SAS/ETS software (1993).

5.A. Gun Homicides and Gun Lethality Measures: Bivariate Models.

Tables 9 and 10 present the results of bimonthly and quarterly bivariate models relating the gun measures to levels of gun homicide.[20] The bimonthly estimates reveal statistically significant ($p<=.05$) associations between gun homicides and the measures of large caliber handguns, total large semiautomatics, and large caliber semiautomatic handguns. There was also a moderately significant ($p<=.10$) relationship between the total large firearms measure and gun

[20]Note that several of the bivariate and multivariate equations contain subset ARIMA models within the error term. Subset models are higher order autoregressive or moving average processes with one or more components set to zero. One example would be a second order autoregressive process with the first lag coefficient set to zero. Subset models can be created for both the regular or seasonal component of a time series model (SAS Institute 1993, p. 117).

homicides.[21] All of the aforementioned gun type measures also had statistically meaningful associations with gun homicides at the quarterly level (see table 10).

In contrast, the measures of total semiautomatics and semiautomatic handguns had smaller and generally insignificant associations with gun homicides. Only the quarterly semiautomatic handgun model produced even a moderately significant relationship with gun homicides.

Two patterns stand out in the results. First, the relationships between aggregate gun lethality and gun homicide levels work primarily through handguns, which constitute the majority of crime guns. Second, stopping power appears to be the key gun lethality factor related to gun homicide. All of the significant relationships involve firearms with higher stopping power. The quarterly results indicate

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[21]The gun homicide/total large gun model in table 9 was estimated with the variables in first differences (i.e., each variable was transformed so that the first observation was subtracted from the second observation, the second observation was subtracted from the third observation, and so on). An autocorrelation function calculated from a regression model with the variables expressed in levels showed that the correlation among the error terms tended to die out slowly over several lags, suggesting that the error term was non-stationary (see Appendix C). A non-stationary error term can lead to spurious relationships between time series variables; consequently, the variables should be differenced when the error term is found to be non-stationary (Pankratz 1991). In practice, Pankratz (1991, pp. 37-38) states that variables should be differenced if the ratio of the autocorrelation coefficients to their standard errors does not fall to about 1.6 or less by the fifth or sixth lag. A more formal alternative is to perform a Dickey-Fuller unit root test on the residuals (e.g., see Davidson and MacKinnon 1993, pp. 700-715). Also, as an informal rule of thumb, the variables were differenced if a regression model with the variables in levels required more than two terms to control the non-seasonal autocorrelation in the residuals.

The gun homicide/large caliber handgun equation (model 2 in table 9) also produced fairly large autocorrelation coefficients out to the sixth lag. However, a Dickey-Fuller unit root test performed on the model residuals indicated that they were stationary, and a relatively parsimonious model was constructed using the variables in levels. Nevertheless, a model with the variables expressed in differences yielded a moderately significant (t=1.8) gun effect of 0.48.

that an absolute one percent increase in the percentage of confiscated weapons having higher stopping power (regardless of whether they are semiautomatics) is associated with approximately one additional gun homicide per quarter. The magnitude of this coefficient is very similar to that found by Koper (1995) in his bivariate study of aggregate gun lethality and gun homicides in Kansas City, Missouri.[22]

5.B. Gun Homicides and Gun Lethality Measures: Multivariate Models.

In a second set of time series models, the number of gun robberies committed at each time point was entered as a covariate. These models reveal the consequences of changes in the crime gun arsenal while controlling for trends in the overall level of gun crime.[23] The gun robbery variable also provides some degree of indirect control for unmeasured social factors driving levels of gun violence.[24] The gun robbery variable was logged because it's

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[22]The gun type variables which were significantly related to gun homicides (the large gun/handgun and large semiautomatic gun/handgun measures) had negative correlations with non-gun homicides. In addition, non-gun homicides were regressed on the significant handgun variables (total large caliber handguns and large caliber semiautomatics) in a series of bimonthly and quarterly bivariate models. The total large caliber handgun measure was significantly and positively related to non-gun homicides at the bimonthly level only, but the magnitude of the relationship was half of that found for gun homicides (b=.31). (This model included an ARIMA (1,0,0)(1,0,0) component for the error term [see Appendix C]). The other non-gun homicide models yielded gun type coefficients which were negative and/or negligible.

[23]For example, one might fail to find anticipated relationships between gun lethality variables and gun homicides if periods of relatively high gun lethality coincided with periods when gun crime was at low levels. Similarly, positive bivariate relationships between gun lethality variables and gun homicides could be a spurious artifact of a general increase in gun violence.

[24]Unfortunately, demographic and socioeconomic variables commonly associated with homicide are not generally measured at the spatial and time aggregations appropriate for this study. However, sociological

variability appeared to change substantially during the period (see figure 10).[25]

The bimonthly and quarterly multivariate models are presented in tables 11 and 12, respectively. In the bimonthly models, only the total large semiautomatic and large caliber semiautomatic handgun measures were associated with gun homicides (p<=.10) after controlling for levels of gun robbery. The coefficients for these variables were similar in magnitude to those found in the bivariate analyses, though they were over a third smaller in relative terms. The total large gun and total large handgun measures produced coefficients very similar in magnitude to those for the total large semiautomatic and large semiautomatic handgun measures, but the former coefficients were not statistically significant.

This pattern changed in the quarterly models; the total large gun and large caliber handgun measures had moderately significant associations with gun homicides (p<=.10), while the total large semiautomatic and large semiautomatic handgun measures did not produce significant relationships. The coefficients for the total large gun

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forces related to violence tend to change slowly over time. This investigation's focus on one city over a relatively short time period should limit the amount of variation in some of these variables. The use of gun robbery as a covariate and the use of time series methods to control for remaining within-series correlation in the model residuals both provide some degree of additional control for unmeasured forces which affected the outcome measure. This reduces the chances of finding spurious relationships between the variables, but it does not eliminate the possibility that the regression coefficients are biased by unmeasured factors correlated with the independent variables.

[25]Gun robberies were employed as a covariate rather than gun aggravated assaults because, to a significant degree, homicides and aggravated assaults represent different categorizations of what is arguably the same underlying behavior. In addition, national data suggest that police recording of robberies has been more consistent over time than police recording of aggravated assaults (Jencks 1991).

and large caliber handgun measures were approximately one quarter smaller in the multivariate quarterly models than in the bivariate quarterly models.[26]

Thus, the multivariate models produced somewhat weaker relationships between the gun type measures and gun homicides in terms of magnitude and statistical significance, but they also confirmed certain aspects of the bivariate results. Overall, the significant relationships were most attributable to handguns and to firearms with higher stopping power. At the quarterly level, for example, each one unit increase in the percentage of confiscated handguns with a large caliber was associated with close to one additional gun homicide. In 1981, large caliber handgun represented an average of 44% of handguns per quarter. By 1992, the prevalence of large handguns had risen to

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[26]Although the gun type and gun robbery measures tended to be highly correlated throughout the period (the correlations generally ranged from .7 to .75), the coefficients for the gun type measures and the gun robbery measures had lesser correlations in the .3 to .4 range, indicating that multicollinearity was not highly problematic for the multivariate models.

In addition, alternative multivariate models were estimated in which all variables were expressed in differences. This further reduced the correlations between the parameter estimates for the gun type variables and gun robberies. Differencing time series variables when unnecessary is sometimes thought to remove important information about the long run relationships between the variables. In general, overdifferencing a time series makes the parameter estimates less efficient; however, the estimates will remain unbiased if the model is specified relatively well (Plosser and Schwert 1978). Those models which yielded significant effects in levels (models 5 and 6 in table 11, and models 1 and 2 in table 12) produced very similar coefficients when the variables were differenced, though the coefficients of the differenced models were not significant at conventional levels of statistical significance (in general, this was true for all of the large gun/handgun and large semiautomatic gun/handgun multivariate models). When expressed in differences, for example, model 1 in table 12 produced a large gun effect equal to 0.82 (t value = 1.34), while model 2 produced a large handgun effect of 0.71 (t value = 1.12). (The error term for both models included a moving average parameter at the first lag). Thus, the estimates of the large gun/handgun and large semiautomatic gun/handgun effects in tables 11 and 12 appeared to be robust to alternative model specifications.

61%. Holding other factors constant, therefore, we would predict nearly 14 additional gun homicides per quarter in 1992 relative to 1981 due to this change in the use of large caliber handguns.[27]

However, the gun type measures explained only modest amounts of the variation in gun homicide. In bimonthly and quarterly ordinary least squares models, for example, the significant large handgun and large semiautomatic handgun variables improved the variation explained (i.e., the R-squares) by only 5% to 12% over models regressing gun homicides on gun robberies alone. Hence, gun homicide trends during this period were driven primarily by general trends in violence rather than changes in the types of guns used in crime.

As in the bivariate analyses, the multivariate models did not yield evidence of relationships between gun homicides and confiscations of either total semiautomatic firearms or total semiautomatic handguns. Further, the semiautomatic measures still appeared unrelated to gun homicides after controlling for the caliber composition of the semiautomatic weapons; bimonthly and quarterly models (not shown) in which gun homicides were regressed on gun robberies (logged), the percentage of confiscated handguns which were semiautomatics, and the percentage of semiautomatic handguns having a large caliber also failed to produce evidence of semiautomatic weaponry effects on gun homicides.

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[27]It is also plausible that the effects of the gun type variables vary with the overall level of gun violence. Accordingly, the author estimated a few exploratory models in which quarterly gun homicides were regressed on the large handgun and large semiautomatic handgun measures (separately), while controlling for gun robberies (logged), and an interaction term for the handgun type and gun robbery measures. These efforts were inconclusive because the models produced extremely high correlations between a number of the coefficient estimates, though they did provide some tentative indications that the effects of gun lethality are greater when levels of gun crime are higher.

One point of ambiguity in the results concerns the relative importance of trends in the prevalence of semiautomatics with high stopping power and all firearms with high stopping power. Theoretically, the former are the most lethal firearms because they combine high stopping power, semiautomatic firing, and larger ammunition capacities. Indeed, measures of large semiautomatic weapons often demonstrated relationships with gun homicides that were as large or larger than those produced by the measures of all guns with high stopping power. On the other hand, the large semiautomatic measures did not consistently produce the largest relationships with gun homicides. Moreover, the analyses failed to yield any other evidence of effects attributable to semiautomatic weapons.[28]

The shift towards weapons with higher stopping power was greatest among semiautomatic handguns, and this may explain why some models suggested that large semiautomatics were most closely related to gun homicide trends. It is also possible that confiscated semiautomatics were more likely than other guns to have been associated with gunfire incidents, in which case stopping power trends among semiautomatics would be a better indicator of trends in the criminal arsenal. At any rate, the pattern of results suggests that the stopping power of the

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[28]Attempts were made to explore this issue further by examining whether the effects of large guns (i.e., guns with high stopping power) and semiautomatic guns interacted with one another. Bimonthly and quarterly models were estimated in which gun homicides were regressed on gun robberies (logged), the large caliber handgun measure, the semiautomatic handgun measure, and an interaction term multiplying the two handgun measures. Neither model produced a significant interaction term. However, these models had very high correlations between the coefficients for the gun terms, rendering the results problematic.

Models regressing gun homicides on gun robberies (logged), the total large handgun measure, and the percentage of large caliber handguns which were semiautomatics did not suffer from extreme collinearity problems but, nonetheless, produced inconclusive results.

criminal gun arsenal is the key gun characteristic affecting trends in gun homicide.

5.C. Gun Density and Gun Homicides

Bivariate models regressing gun homicides on the gun density measure failed to produce significant relationships in both the bimonthly (see model 7, table 9) and quarterly (see model 7, table 10) analyses. In a second set of analyses, the number of total robberies occurring at each time point was used as a covariate to control for trends in violent crime levels.[29] Nevertheless, these models also showed no relationship between gun density and gun homicides (see model 7 in tables 11 and 12).[30]

It seems that the overall availability of guns - reflecting conditions of both supply and demand (see Cook 1979, pp. 750-752) - remained relatively stable in Dallas during this period (despite the general increase in gun violence) and did not cause the general rise in gun homicides in Dallas.[31] In contrast, the gun type analyses

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[29]The bivariate relationship between gun homicides and gun density could have been confounded by the possibility that the fraction of robberies committed with guns was low at a time when absolute levels of gun and non-gun violence were higher or visa versa. The gun density and total robbery variables had modest correlations of -.24 at both the bimonthly and quarterly levels.

[30]The multivariate quarterly model (model 7) in table 12 produced a Q statistic with a p level of .096 at six lags, indicating that autocorrelation may not have been sufficiently controlled. This was attributable to a rather large autocorrelation coefficient at the fifth lag. Q statistics calculated at the 12th, 18th, and 24th lags were not significant. A number of alternative model specifications (including models with the variables expressed in differences) also did not yield evidence of a significant gun density effect.

[31]These results do not mean that more gun crime does not result in more gun deaths. As was shown in the gun type analyses, for instance, the number of gun robberies occurring at a given point in time is significantly and positively related to the number of gun homicides

indicate that there was an increase in the availability of more lethal types of firearms, and that the substitution of more lethal firearms for less lethal firearms (measured by stopping power) contributed to the rise in gun homicides in Dallas.

However, a few caveats should be offered. The failure to find a significant association between gun density and gun homicide in this study is consistent with results found by Koper (1995) and others (e.g., Kleck 1984; 1991), but is inconsistent with the results of a number of other studies finding relationships between gun density and different categories of murder (e.g., Cook 1979; Kleck 1979; McDowall 1991). Differences in the operationalization of the gun density measure in this study and other studies may be responsible in part for the discrepant results. Perhaps more importantly, prior studies finding relationships between gun density and homicide have used data aggregated at temporal periods of one year or longer. The bimonthly and quarterly time intervals used in this study and Koper's (1995) Kansas City study may be too small to show a relationship between gun density and gun homicides. If gun use in robbery is primarily related to robbery murders, for example, gun density effects may not be apparent unless one is examining time periods with sufficient numbers of robbery murders. It is also possible that inconsistencies or other problems in the recording of robberies could obscure gun density effects based on a robbery measure, particularly when using smaller time periods. Thus, the gun density models may have suffered from excessive temporal disaggregation of the data (Plosser and Schwert

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committed during that time; i.e., more gun violence results in more gun homicides.

1978).[32]

Another important issue is that while the fraction of robberies committed with guns was relatively stable, the fraction of aggravated assaults committed with guns rose. Gun aggravated assaults accounted for 35% of aggravated assaults in Dallas from 1980-1982 and 50% from 1990-1992. Hence, trends in assaultive behavior with guns may have been a key variable affecting gun homicide trends in Dallas.

Aggravated assaults were not incorporated into the gun density measure because of the conceptual, behavioral overlap between homicides and aggravated assaults. These crimes arguably represent different manifestations of the same underlying behavior, and using one to predict the other in a regression model thus seems problematic. In addition, police reporting seems to have been more consistent over time for robberies than for aggravated assaults, implying that measurement of aggravated assaults is subject to greater measurement

[32]Auxiliary analyses conducted with the quarterly data suggested that seasonal or semi-seasonal patterns may have also influenced the results. The gun density measure tended to follow a modest semi-seasonal pattern, rising during colder months and declining during warmer months. This would seem to be attributable to the greater ease of concealing weapons in heavier clothing worn during cooler weather and/or a lower fraction of planned, premeditated robberies occurring during warm months. Exploratory gun density models including a warm/cold weather variable provided indications of positive and statistically significant relationships between the gun density measure and gun homicides. This might suggest that unmeasured factors tend to drive up gun homicides during warmer periods when gun use in robbery is lower. However, the models presented in the text controlled for overall levels of robbery; hence, any seasonal increases in robbery levels were held constant in those models (moreover, total robberies had very little correlation with the warm/cold variable). An alternative explanation might be, for example, that gun attacks occurring during warm weather are more likely to be unplanned attacks in which fewer offenders have sustained intent to kill. Such explanations are very speculative at this point. More importantly, these potentially confounding factors would not alter the primary conclusions drawn in the text. The gun density measure remained relatively constant during the study period and did not appear to drive gun homicide trends.

error (Jencks 1991). Yet the differential trends in gun use for robberies and aggravated assaults raise interesting interpretive questions. Setting aside the possibility of differential trends in the reporting and recording of gun robberies and gun assaults, robberies would, in general, seem more likely than aggravated assaults to involve premeditation and planning by offenders. In that respect, gun robberies would seem to be a better indicator of the availability of weapons for crime. Gun assaults, which are more likely to be spontaneous events, may have more relevance to changes in gun carrying. The increasing use of guns in aggravated assaults may be indicative of important changes in the population's gun carrying behavior. In future research, it would seem useful to construct more explicit indexes of gun carrying by criminal/high risk populations.

5.D. A Note on Potential Feedback Processes

The preceding analyses assume that causality is unidirectional from the gun measures to the outcome measures. Although there is currently no evidence that gun violence influences the acquisition and use of particular types of guns, prior research has shown that violence rates influence gun density (McDowall 1986; Kleck 1984b; also see Bordua 1986; McDowall and Loftin 1983; Young et al. 1987). However, those studies were based on data corresponding to time intervals of a year or longer. It seems less likely that contemporaneous feedback processes would exist at the smaller time intervals examined in this study. Further, we can expect that failure to account for contemporaneous feedback from the gun homicide measure would most likely result in finding a spurious positive relationship between gun density and gun homicide, a result not borne out by this analysis.

To tentatively examine whether gun violence influences the acquisition and use of particular types of guns, a series of exploratory Granger causality tests (Pankratz 1991, pp. 170-173) were run with gun homicides and the gun type measures. Each gun type variable was regressed upon lagged values of itself and then upon lagged values of itself and lagged values of gun homicide to determine whether the inclusion of the lagged gun homicide measures improved the models (six lags were used for the bimonthly tests and quarterly tests were conducted using both four lags and eight lags). There did not appear to be significant feedback (F tests showed $p>.10$) from gun homicides to the gun type measures significantly related to gun homicides (total large guns, large handguns, total large semiautomatics, and large semiautomatic handguns). Although these feedback tests do not provide direct information on the contemporaneous relationships between the variables, it seems likely that any feedback from gun homicides would operate on a lagged basis as well as contemporaneously. The absence of lagged feedback makes it seem even more unlikely that the results of the gun type models were confounded by contemporaneous feedback processes.

5.E. Gun Lethality and the Fatality Rate of Gun Attacks

Another method of assessing the relationship between aggregate gun lethality and gun violence mortality while holding levels of gun violence constant is to examine the association between the gun type measures and the percentage of gun attacks resulting in death. Accordingly, tables 13 and 14 present the results of models in which the gun attack fatality measure was regressed upon the various gun type measures.

Based on preliminary analyses, the models were estimated with a time trend variable to capture the overall downward trend of the fatality measure and a set of seasonal dummy variables to control seasonal variation. As is shown in figure 8, the fatality rate measure actually declined during the later years of the study period while aggregate gun lethality was rising. This downward trend may have been caused by a number of factors. As was discussed in Chapter 3, for example, the fatality rate is likely to have been influenced by improvements in the recording of non-fatal crimes. Changes in the offender population may have played a role as well.[33] The time trend variable was therefore used as a crude proxy for unmeasured factors causing the downward trend in the gun attack fatality rate.

Finally, the fatality measure was logged because its variation decreased substantially during the later years of the study period (see figure 8). Diagnostic statistics revealed that there was no remaining autocorrelation in the residuals of these models. Thus, it was unnecessary to add time series components to the error terms, and the estimates in the tables are ordinary least squares estimates.[34]

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[33]To illustrate, some accounts suggest an increase in the purposeful infliction of non-fatal gunshot wounds to extremities as a form of intimidation or punishment, particularly among drug-involved persons (Sanchez et al. 1989, p. 1089). In addition, an increase in gun carrying during this period may have led to more cases of firearm threats and/or brandishings relative to shootings. A rise in gun use by unskilled shooters, particularly youthful gun offenders, may have also resulted in more attempted shootings which did not result in gunshot wounds to intended targets.

[34]As in the previous sections, these analyses assume that causality is unidirectional from the gun type measures to the gun attack fatality rate measure. As a side note, feedback tests like those described in the previous section suggested there was no substantial lagged feedback from the fatality rate measure to the gun type measures, thus making contemporaneous feedback problems seem more improbable.

The measures of total semiautomatics, semiautomatic handguns, total large semiautomatics, and large semiautomatic handguns were all significantly related ($p<=.05$) to the fatality rate measure in the bimonthly models. In the quarterly models, the relationships were significant at the $p<=.10$ level. The coefficients for total large guns and large handguns were not statistically significant, but they were nearly the same in magnitude as were the coefficients for the other gun measures.[35]

In general, the results may signify that the rapid fire ability and larger ammunition capacities of semiautomatics tend to enhance the ability of gun offenders to hit one or more victims in an attack, thereby raising the percentage of gun attacks in which one or more persons sustain at least one gunshot wound and raising the fatality rate of gun attacks. The stopping power effects attributable to large guns, on the other hand, are contingent upon gun attackers hitting their victims. Consequently, the instrumentality effects of non-semiautomatic large guns are relevant to a smaller subset of gun attacks than are the instrumentality effects of semiautomatics. Yet as discussed previously, the fatality measure employed in this study is based on all gun aggravated assaults, including those resulting in no gunshot wounds and even those resulting in no gun discharge.

The gun term effects were all approximately .01. Because the

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[35]Another cautionary note is that all of the models had notable correlation between the gun type and time trend parameter estimates. To illustrate, the bimonthly total large gun coefficient had a correlation of -.866 with the time trend estimate. The total semiautomatic and total large semiautomatic models produced comparable (but somewhat higher) correlations. Additional attempts to disentangle the unique effects of semiautomatics and large guns, such as regressing the fatality rate on the time and seasonal variables, the semiautomatic handgun measure, and the large handgun measure, did not produce consistent evidence of caliber effects on the fatality rate.

dependent variable was logged, the effect is interpreted by exponentiating the coefficient. This results in a value of $e^{0.01}$ = 1.01. This number is a multiplier effect, and it indicates that each one unit change in the gun variable multiplies the fatality rate by 1.01. In other words, the fatality rate is increased by 1% in relative terms for each one unit change in the predictor variable.

These results imply substantial weapon lethality effects when considered in light of the large increase in the use of semiautomatic weapons. To illustrate, semiautomatic handguns rose from 24% of handguns in 1980 to 65% in 1992, an absolute change of 41 units. The multiplier effect suggests that this change in the use of semiautomatics would have resulted in a fatality rate 50% higher in 1992 than in 1980 had other factors remained constant.

The fact that the fatality rate actually declined indicates that other important factors were at work. Indeed, the gun variables added little to the prediction of the fatality rate. In both the bimonthly and quarterly models, none of the gun variables improved the variation explained by more than 3% to 4% over models including just the time trend and seasonal variables as predictors.

An additional caveat is that the gun effects may be biased by unmeasured changes in offender behavior coinciding with the rise in semiautomatic weaponry. The deadliness of gun attacks can vary notably both between cities and within cities over time (Cook 1982). Prior research has also provided examples of rather sudden changes in the death rate of gun robberies (Zimring 1977) and gun assaults (Swersey 1980, cited in Cook 1982) which appeared to be associated with changes in offender behavior (and possibly that of victims) rather than changes in weaponry.

Finally, the substantial measurement problems inherent in the fatality rate measure (also see Chapter Three) warrant that these results should be treated very cautiously. Further study of this issue would certainly seem worthwhile, however, with emphases on the construction of more refined measures of the gun attack fatality rate (e.g., the fatality rate of all gun attacks in which firearms are discharged and/or gunshot wounds inflicted), additional research on biases and trends in police reporting of aggravated assaults, and more in-depth study of the dynamics of gun attacks, including examinations of shots fired and wounds inflicted.[36]

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[36]Using measures operationalized in the same manner as those in this study, Koper (1996, pp. 174-177) did not find significant relationships between measures of gun lethality and the fatality rate of gun attacks in Kansas City, MO from 1985 through 1993. Using data from the Kansas City Police Department, Koper was also able to create a gun attack fatality measure based on only those cases resulting in some sort of injury to the victim (the nature of the injuries could not be determined, so it is likely that some of these injuries were not gunshot wounds). This measure also failed to have significant associations with the gun type measures. Although the results were not statistically significant, the fatality rate measures tended to have more positive associations with measures of large guns and large handguns.

To some extent, the different results of that study and the current investigation may have stemmed from differences in methodology. The Kansas City time series were shorter than those used in this study, and the series were related using the cross-correlation function method described in McCleary and Hay (1980, pp. 227-273).

6. CONCLUSIONS

6.A. Summary and Discussion of Results

This study has used data from Dallas, Texas for the period 1980-1992 to examine the relationship between deadly gun violence and the aggregate characteristics of guns used in crime as measured by firearms confiscated by police. The prevalence of semiautomatics and larger caliber, higher velocity firearms (i.e., firearms with higher stopping power) increased substantially among firearms confiscated in Dallas during this period. These changes in the gun arsenal did not explain much of the variation in Dallas' gun homicides, but they were a contributing factor to gun homicide trends. More specifically, a rise in the use of firearms with higher stopping power (i.e., shotguns, centerfire rifles, and large caliber handguns) contributed to the growth in gun homicides in Dallas.

Trends in the use of semiautomatic firearms, on the other hand, were not clearly related to gun homicides. Although confiscations of larger caliber, higher velocity semiautomatics bore some relationship to gun homicides, the general pattern of results suggests that these were stopping power effects. This strengthens the contention of those who argue that semiautomatics' faster firing rate and larger ammunition capacities are limited in their effects on criminal attack outcomes by, respectively, the effect of recoil on shooter aim and the limited number of shots fired in most criminal attacks (Kleck 1991, pp. 78-79). Lack of skill and experience on the part of many gun offenders, especially young offenders, may place further limits on the potential of semiautomatic use to raise the lethality of gun violence.

On the other hand, the use of semiautomatics did appear to be positively related to the percentage of gun attacks resulting in death, whereas the total large gun/handgun measures were not. This may be an indication that the use of semiautomatics enables offenders to fire greater numbers of shots in criminal attacks and raises the proportion of gun attacks in which one or more victims are hit. We were unable to examine whether greater use of semiautomatics actually resulted in more shots fired per incident or more wounds inflicted per incident - an important question for future research - and in view of substantial measurement problems with the fatality rate outcome measure, these results should be treated very tentatively. An additional limitation is that we were unable to explcitly measure trends in the use of semiautomatics with large capacity magazines.

The study also revealed that gun density remained relatively stable in Dallas throughout this period and was not significantly associated with gun homicides. Though the gun type and gun density measures were not entirely compatible (only the latter measure was a direct measure of gun use in crime), the results suggest that the availability of more lethal guns (particularly as measured by firearm stopping power) is, at least in some contexts, more consequential than the general availability of firearms.

In sum, homicide trends in Dallas were driven primarily by changes in the behavior of the population. Both gun and non-gun violence rose in Dallas during the late 1980s and early 1990s, fueled presumably by various forces affecting big-city violence rates throughout the country (see Reiss and Roth 1993). At the same time, the substitution of more lethal firearms for less lethal firearms heightened the lethality of gun violence, thereby contributing to the increase in gun homicides.

A number of limitations to the study should be noted. The gun lethality measures were based on all confiscated firearms. Therefore, they represent only an approximation of violent crime guns. Many confiscated firearms are not known to have been used in violence, and many guns used in violent crime are never confiscated by police. It is also plausible that more specific gun samples tied to particular types of crimes or particular types of offenders could be related differently to gun violence outcomes. For example, the use of semiautomatic weaponry might have a more measurable impact in the context of crimes like drive-by shootings, in which attackers spray bullets at a person, crowd, or dwelling (e.g., see Sherman et al. 1989). By the same token, weapon caliber is likely to matter less when killers subdue their victims and slay them in execution-style fashion.

Furthermore, the results may have been sensitive to the relatively short time period and small time intervals used in this study. For example, other longitudinal research has shown gun density to predict homicides on an annual basis (e.g., McDowall 1991).

Finally, our ability to control for sociological forces affecting homicide was limited, so we cannot entirely dismiss the possibility that our estimates were biased by unmeasured factors. It is unclear, however, whether the inclusion of such variables would weaken or strengthen the relationships between the gun type/density and gun violence mortality measures. Considering the former possibility, for instance, National Crime Victimization Survey data reveal that offenders discharged their firearms in 12.6% of non-fatal handgun crimes during the 1979-1987 period (Rand 1990) and 16.6% during the 1987-1992 period (Rand 1994, p.2). This may signal a recent change in the willingness of offenders to use lethal force (i.e., offender dangerousness) that is perhaps correlated with weaponry selection and was not adequately captured by the models. On the other hand, there are anecdotal indications that doctors in urban areas are becoming more skilled at treating gunshot victims (Leary 1994; Webster et al. 1992). Such advances have likely worked counter to the effects of increasing gun lethality, and a proper measurement of this factor might have resulted in finding stronger relationships between gun lethality and homicide. At any rate, the gun homicide results in this study are quite similar to those found in Koper's (1995) study of this issue in Kansas City, Missouri. Thus, data from two cities have suggested a link between the use of guns with higher stopping power and levels of gun homicide.

At this point, a prudent conclusion is that the most credible evidence suggests criminal use of guns with higher stopping power is more consequential in the aggregate than is criminal use of semiautomatics. To the extent that these results are generalizable to other areas, they also imply that changes in the availability of more powerful guns (particularly large caliber handguns) have been more consequential than changes in overall gun availability in recent years (indeed, the latter seems to have stabilized). This finding is also consistent with Koper's (1995) study of the issue in Kansas City.

6.B. Implications for Research and Policy

This study has shown that the crime gun arsenal has become more lethal in recent years, and that this trend has had negative consequences on public safety. Both the citizenry and law enforcement officers are faced with an increasingly lethal street gun arsenal. This investigation thus lends greater urgency to the argument that law enforcement agencies should place greater emphasis on targeting illegal firearms traffic, firearms thefts, and illegal gun carrying and undertake further experimentation on strategies (e.g., Sherman et al. 1995; Pierce et al. 1995) and technologies (e.g., U.S. National Institute of Justice 1995, pp. 35-38) to help achieve these goals. In addition, the findings support the utility of greater use of bullet-proof vests by law enforcement officers.

By extension, the findings regarding the importance of firearm stopping power imply that gun control policies directed at limiting the distribution of new types of especially lethal ammunition may be beneficial. Examples would be the armor-piercing "cop killer" bullets banned by the federal government in 1986 (also see U.S. Bureau of Alcohol, Tobacco, and Firearms 1994b) or the recently-developed Rhino bullets which, prior to being pulled from the market, were said to fracture into "...thousands of sharp, razorlike fragments...hurled into vital organs, lungs, circulatory-system components, the heart and other tissues" (Newsweek 1994, p. 8). In some cases, claims regarding such ammunition may be overstated (see Kleck 1991, p. 83 on "cop killer" bullets), but limitations on some ammunition (within the bounds of constitutional and political constraints) may be an effective prevention measure designed to reduce or prevent increases in the lethality (i.e., stopping power) of the street gun arsenal.[37]

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[37]This recommendation does not include limitations on hollow point handgun ammunition. Such ammunition is designed to mushroom after penetration. This causes the bullet to slow down more quickly, lowering the chance that it will pass through the body and increasing the amount of energy delivered by the bullet to the body (DiMaio 1985; Hollerman 1988). Because these bullets have been available for many years, reducing their stock would raise substantial practical difficulties. Moreover, DiMaio (1985, p. 310) has observed that the differences in lethality between hollow point handgun ammunition and ordinary solid lead bullets are "...probably only theoretical." For example, he reported that an examination of over 75 deaths with hollow

As of yet, however, there have been no evaluations of the preventive effects or cost effectiveness of such measures (Reiss and Roth 1993, p. 272).

The results also lend more weight to concerns that bans on small, cheap "Saturday night special" handguns could have adverse consequences by fostering a shift to larger caliber handguns and long guns on the part of gun offenders (Kleck 1991; Wright and Rossi 1986). This study cannot address the extent to which such substitution would occur, but it strengthens the empirical basis for the claim that any such shift could be expected to heighten the deadliness of gun violence.

The results concerning semiautomatic weapons are more ambiguous. The results of this study raise questions about the potential impact of both restrictions on semiautomatics or large capacity ammunition magazines and penalty enhancements intended to discourage the use of semiautomatics, both of which were imposed by the federal <u>Violent Crime Control and Law Enforcement Act of 1994</u> (also see Roth and Koper 1997). There is a clear need, however, for more incident-based research to investigate whether gun attacks with semiautomatics result in more shots fired and more gunshot wounds than do attacks with other firearms.

More generally, this study implies that further attempts by public officials and researchers to track changes in crime weaponry,

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point handgun ammunition did not reveal any deaths which would not have occurred with ordinary lead bullets (1985, p. 241). Likewise, Hollerman (1988, pp. 232-233) has noted that hollow point bullets generally need magnum loads to generate enough velocity for a mushrooming effect. Therefore, it seems that bullet construction matters more for high-velocity weapons (such as magnum handguns) than for comparatively lower-velocity weapons (such as most non-magnum handguns).

and perhaps changes in weaponry used by particularly dangerous groups such as urban gang members, would yield important data. Likewise, medical researchers have advocated the establishment of firearm injury/fatality reporting systems (Teret et al. 1992) to examine trends in injuries and fatalities committed with guns of different calibers and types (also see Lee et al. 1991; Wintemute 1994b). Also, future gun density studies should, wherever possible, take into account the density of particular types of guns. This study utilized simple dichotomies to measure firearm characteristics; future studies may yield more refined quantification of the aggregate lethality of crime guns. In sum, further research on trends in crime weaponry, complemented by incident-based research on the influence of weaponry characteristics on gun attack outcomes, can build on this study by helping us to better understand the consequences of the evolving technology of personal violence (Cook 1991) and by providing insights intc the utility of different law enforcement and legislative policies to reduce gun crime and injuries.

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Table 1. Characteristics of Confiscated Firearms in Dallas, 1980-1992.

Year	Confiscated Firearms (approx.)	Handguns (%)	Rifles (%)	Shotguns (%)
1980	2,988	82%	7%	11%
1981	2,883	83%	6%	11%
1982	1,794	84%	6%	9%
1983	2,924	83%	6%	11%
1984	3,518	82%	7%	11%
1985	3,968	82%	7%	11%
1986	5,149	81%	7%	12%
1987	4,851	81%	7%	13%
1988	5,007	80%	7%	13%
1989	5,394	80%	7%	13%
1990	5,771	80%	6%	14%
1991	6,924	82%	6%	12%
1992	6,820	83%	5%	12%

Notes:

Figures are based on quarterly gun confiscations and represent firearms for which weapon type, caliber, and approximate confiscation date could be ascertained (see Appendix B). Figures for 1980-1983 represent 85% to 95% of guns (see Appendix B for additional notes regarding 1982 data). Figures for 1984-1992 represent 97% to 100% of guns.

Percentages may not sum to 100% due to rounding.

Table 2. Stopping Power of Confiscated Firearms in Dallas, 1980-1992

Year	Lg Cal Handguns, Shotguns, and High Velocity Rifles as % of All Guns	Lg Cal Handguns as % of All Handguns	Shotguns and High Velocity Rifles as % of Long Guns
1980	51	45	79
1981	51	44	81
1982	48	44	73
1983	51	45	84
1984	54	48	80
1985	54	48	78
1986	55	50	79
1987	58	52	80
1988	59	54	82
1989	58	53	81
1990	60	54	84
1991	64	60	84
1992	65	61	86

Notes:

Handguns larger than .32 caliber were classified as large caliber. Rifles having other than .22 caliber were classified as high velocity rifles.

Figures are based on quarterly gun confiscations and represent firearms for which weapon type, caliber, and approximate confiscation date could be ascertained (see Appendix B).

Table 3. Semiautomatic Firearms Confiscated in Dallas, 1980-1992

Year	Semiautomatics as % of All Guns	Semiautomatics as % of Handguns	Semiautomatics as % of Long Guns
1980	23	24	20
1981	23	24	20
1982	26	27	23
1983	30	31	22
1984	31	33	23
1985	33	35	24
1986	34	36	23
1987	34	36	24
1988	36	38	24
1989	40	44	24
1990	44	49	23
1991	53	59	23
1992	58	65	21

Notes:

Figures are based on quarterly gun confiscations and represent firearms for which weapon type, caliber, and approximate confiscation date could be ascertained (see Appendix B).

Table 4. Combination of High Stopping Power and Semiautomatic Firing Among Confiscated Firearms in Dallas, 1980-1992

Year	Lg Cal Semi Handguns, Semi Shotguns, and High Velocity Semi Rifles as % of All Guns	Lg Cal Semi Handguns as % of All Handguns	Semi Shotguns and High Velocity Semi Rifles as % of Long Guns
1980	8	8	10
1981	8	7	11
1982	8	8	9
1983	10	9	13
1984	11	11	12
1985	12	12	11
1986	13	14	11
1987	14	14	13
1988	16	17	14
1989	17	19	12
1990	21	22	14
1991	29	33	13
1992	34	38	14

Notes:

Handguns larger than .32 caliber were classified as large caliber. Rifles having other than .22 caliber were classified as high velocity rifles.

Figures are based on quarterly gun confiscations and represent firearms for which weapon type, caliber, and approximate confiscation date could be ascertained (see Appendix B).

Table 5. Most Common Handgun Calibers in Dallas, 1980-1992 (Expressed as %'s of all Conficated Handguns).

Year	22	25	32	380	38	9mm	357	Other
1980	30%	10%	12%	3%	29%	3%	6%	7%
1981	31%	12%	11%	2%	29%	3%	6%	6%
1982	30%	15%	10%	3%	28%	3%	6%	5%
1983	28%	17%	9%	3%	28%	4%	6%	5%
1984	26%	17%	8%	4%	29%	4%	7%	5%
1985	26%	16%	8%	4%	28%	4%	7%	7%
1986	24%	16%	9%	4%	26%	6%	8%	7%
1987	24%	15%	7%	5%	26%	7%	9%	7%
1988	22%	15%	9%	4%	26%	9%	9%	6%
1989	21%	18%	8%	5%	22%	10%	9%	7%
1990	18%	19%	8%	6%	21%	13%	9%	6%
1991	14%	19%	6%	10%	18%	18%	7%	8%
1992	14%	19%	5%	16%	16%	18%	6%	6%

Notes:

Listed calibers accounted for 5% or more of confiscated handguns in at least one year of the study.

Figures are based on quarterly gun confiscations and represent firearms for which weapon type, caliber, and approximate confiscation date could be ascertained (see Appendix B).

Table 6. Most Common Semiautomatic Handgun Calibers in Dallas, 1980-1992 (Expressed as %'s of All Confiscated Semiautomatic Handguns).

Year	22	25	32	380	9mm	45	Other
1980	11%	46%	5%	12%	11%	7%	8%
1981	11%	49%	5%	10%	10%	9%	6%
1982	14%	52%	2%	12%	11%	4%	5%
1983	11%	49%	4%	9%	13%	6%	8%
1984	11%	50%	3%	11%	13%	7%	5%
1985	13%	46%	3%	11%	13%	8%	6%
1986	11%	43%	4%	12%	16%	8%	6%
1987	13%	41%	3%	13%	18%	8%	4%
1988	10%	38%	5%	11%	23%	8%	5%
1989	11%	39%	5%	11%	23%	7%	4%
1990	9%	38%	5%	13%	26%	4%	5%
1991	7%	32%	4%	18%	30%	6%	3%
1992	8%	29%	3%	24%	27%	6%	3%

Notes:

Listed calibers accounted for 5% or more of confiscated semiautomatic handguns in at least one year of the study.

Figures are based on quarterly gun confiscations and represent firearms for which weapon type, caliber, and approximate confiscation date could be ascertained (see Appendix B).

Table 7. Most Common Non-Semiautomatic Handgun Calibers in Dallas, 1980-1992 (Expressed as %'s of All Confiscated Non-Semiautomatic Handguns).

Year	22	32	38	357	Other
1980	36%	14%	38%	8%	4%
1981	38%	12%	38%	8%	4%
1982	36%	13%	38%	8%	5%
1983	36%	11%	39%	9%	5%
1984	34%	10%	41%	10%	5%
1985	33%	10%	42%	10%	5%
1986	31%	11%	40%	12%	6%
1987	31%	10%	41%	14%	4%
1988	29%	11%	41%	14%	5%
1989	29%	10%	39%	16%	6%
1990	27%	10%	41%	17%	5%
1991	25%	9%	43%	17%	6%
1992	25%	9%	43%	16%	7%

Notes:

Listed calibers accounted for 5% or more of confiscated non-semiautomatic handguns in at least one year of the study.

Figures are based on quarterly gun confiscations and represent firearms for which weapon type, caliber, and approximate confiscation date could be ascertained (see Appendix B).

Table 8. Violence and Gun Density Measures For Dallas, 1980-1992.

Year	Total Homicides (Rate per 100,000)	Gun Homicides (Rate per 100,000)	Percentage of Homicides With Guns	Fatality Rate of Gun Attacks (Gun Attacks)*	Percentage of Robberies With Guns (Gun Robberies)
1980	320 (35.4)	228 (25.2)	71%	10% (2,398)	52% (2,611)
1981	302 (33.3)	211 (23.3)	70%	9% (2,236)	50% (2,709)
1982	305 (33.3)	205 (22.4)	67%	9% (2,305)	51% (2,885)
1983	269 (29.1)	170 (18.4)	63%	9% (1,947)	46% (2,237)
1984	296 (31.9)	184 (19.9)	62%	8% (2,176)	45% (2,176)
1985	304 (32.1)	210 (22.2)	69%	8% (2,581)	48% (2,902)
1986	347 (35.8)	217 (22.4)	63%	7% (3,241)	45% (4,207)
1987	326 (33.4)	210 (21.5)	64%	6% (3,580)	43% (3,871)
1988	365 (37.1)	259 (26.3)	71%	6% (4,244)	41% (3,929)
1989	357 (35.7)	277 (27.7)	78%	6% (4,733)	39% (3,712)
1990	451 (44.8)	363 (36.1)	80%	6% (6,146)	46% (4,854)
1991	507 (50.1)	413 (40.8)	81%	6% (7,196)	48% (5,407)
1992	401 (39.5)	333 (32.8)	83%	6% (5,872)	51% (4,873)

* Gun Attacks = Gun Homicides + Gun Aggravated Assaults
Fatality Rate = (Gun Homicides/Gun Attacks) * 100

Additional Notes:

Crime figures were taken from the FBI's Uniform Crime Reports and Supplemental Homicide Reports. Homicide figures exclude justifiable homicides and negligent manslaughters.

Population figures (for the calculation of homicide rates) were provided by the Office of Budget and Management Services of the City of Dallas.

Table 9. Bimonthly Bivariate Time Series Regressions of Gun Homicides on Measures of Gun Lethality and Gun Density (N=78)

Gun Measures	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Large Guns +	0.52 t=1.87*						
Large Handguns		0.61 t=2.20**					
Semis			0.27 t=0.83				
Semi Handguns				0.29 t=1.08			
Large Semis					0.74 t=2.31**		
Large Semi Handguns						0.62 t=2.24**	
Gun Density +							0.28 t=1.20
Other Model Parameters:							
μ	0.12	10.98	32.80	31.14	30.27	31.57	0.22
$\phi1$		0.52	0.42	0.42	0.42	0.43	
$\phi2$			0.34	0.33	0.30	0.28	
$\phi3$	-0.31						-0.31
$\phi4$		0.31					
$\phi12$			0.31	0.29	0.29	0.29	
$\theta1$	0.51						0.54
Q	11.96 df=16 p=.75	22.64 df=16 p=.12	15.39 df=15 p=.42	15.12 df=15 p=.44	14.25 df=15 p=.51	14.54 df=15 p=.49	13.27 df=16 p=.65
SE	7.82	7.91	7.88	7.87	7.71	7.73	7.91

μ Denotes constant term. ϕn Denotes autoregressive parameter at the nth lag. θn Denotes moving average parameter at the nth lag. (See Appendix C). All autoregressive and moving average parameters were significant at p<=.05. Q Denotes Ljung-Box chi-square statistic for residual autocorrelation (calculated at the 18th lag). SE Denotes residual standard error of model.

Table 9 notes (continued)

+ Model was estimated with variables in first differences (N=77).
* Gun effect significant at p<=.10.
** Gun effect significant at p<=.05.

Table 10. Quarterly Bivariate Time Series Regressions of Gun Homicides on Measures of Gun Lethality and Gun Density (N=52)

Gun Measures	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Large Guns	1.06 t=2.07**						
Large Handguns		1.11 t=2.12**					
Semis			0.62 t=1.35				
Semi Handguns				0.65 t=1.81*			
Large Semis					1.12 t=2.16**		
Large Semi Handguns						0.96 t=2.16**	
Gun Density +							0.41 t=0.88
Other Model Parameters:							
μ	4.63	7.64	41.85	38.81	45.85	47.43	0.15
$\phi 1$	0.66	0.65	0.62	0.59	0.60	0.60	
$\phi 8$	0.39	0.40	0.39	0.37	0.39	0.39	0.35
$\theta 1$							0.51
Q	6.15 df=10 p=.80	6.02 df=10 p=.81	4.15 df=10 p=.94	3.85 df=10 p=.95	4.64 df=10 p=.91	4.48 df=10 p=.92	4.67 df=10 p=.91
SE	11.93	11.90	12.31	12.24	12.01	11.98	12.23

μ Denotes constant term. ϕn Denotes autoregressive parameter at the nth lag. θn Denotes moving average parameter at the nth lag. (See Appendix C). All autoregressive and moving average parameters were significant at the p<=.05 level. Q Denotes Ljung-Box chi-square statistic for residual autocorrelation (calculated at the 12th lag). SE Denotes residual standard error of model.

+ Model was estimated with variables in first differences (N=51).
* Gun effect significant at p<=.10.
** Gun effect significant at p<=.05.

Table 11. Bimonthly Time Series Regressions of Gun Homicides on Measures of Gun Lethality and Gun Density, Controlling for Levels of Robbery (N=78)

Gun Measures	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Large Guns +	0.44 t=1.60						
Large Handguns		0.39 t=1.55					
Semis			0.26 t=1.29				
Semi Handguns				0.24 t=1.40			
Large Semis					0.45 t=1.84*		
Large Semi Handguns						0.40 t=1.86*	
Gun Density +							0.10 t=0.55
Other Model Parameters:							
μ	-0.01	-105.32	-98.62	-97.54	-90.08	-88.58	0.00
grobs (logged)	17.99	20.14	20.77	20.60	19.74	19.59	
robs							0.02
$\phi1$		0.34	0.32	0.31	0.32	0.32	
$\phi3$	-0.24						
$\phi4$		0.37	0.37	0.36	0.35	0.34	
$\theta1$	0.62						0.70
Q	11.09 df=16 p=.80	18.26 df=16 p=.31	15.08 df=16 p=.52	15.49 df=16 p=.49	16.15 df=16 p=.44	15.96 df=16 p=.46	19.31 df=17 p=.31
SE	7.34	7.28	7.33	7.31	7.25	7.24	7.30

μ Denotes constant term. ϕn Denotes autoregressive parameter at the nth lag. θn Denotes moving average parameter at the nth lag. (See Appendix C). All autoregressive, moving average, gun robbery, and total robbery parameters were significant at p<=.05. Q Denotes Ljung-Box chi-square statistic for residual autocorrelation (calculated at the 18th lag). SE Denotes residual standard error of model.

Table 11 notes (continued)

+ Model was estimated with variables in first differences (N=51).
* Gun effect significant at p<=.10 level.

Table 12. Quarterly Time Series Regressions of Gun Homicides on Measures of Gun Lethality and Gun Density, Controlling for Levels of Robbery (N=52)

Gun Measures	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Large Guns	0.81 t=1.74*						
Large Handguns		0.81 t=1.70*					
Semis			0.19 t=0.49				
Semi Handguns				0.22 t=0.71			
Large Semis					0.51 t=1.19		
Large Semi Handguns						0.45 t=1.25	
Gun Density +							0.44 t=1.14
Other Model Parameters:							
μ	-224.26	-217.22	-197.46	-194.94	-188.20	-186.15	112.16
grobs (logged)	35.95	35.51	37.74	37.07	36.13	35.90	
robs							0.03
$\phi 1$	0.34	0.33	0.32	0.32	0.31	0.31	0.33
$\phi 3$	0.32	0.34	0.33	0.32	0.51	0.31	0.35
$\theta 1$							
Q	8.28 df=10 p=.60	9.04 df=10 p=.53	9.50 df=10 p=.49	8.94 df=10 p=.54	9.32 df=10 p=.50	9.08 df=10 p=.52	11.33 df=10 p=.33
SE	10.78	10.78	11.08	11.06	10.97	10.95	10.59

μ Denotes constant term. ϕn Denotes autoregressive parameter at the nth lag. θn Denotes moving average parameter at the nth lag. (See Appendix C). All autoregressive, moving average, gun robbery, and total robbery parameters were significant at p<=.05. Q Denotes Ljung-Box chi-square statistic for residual autocorrelation (calculated at the 12th lag). SE Denotes residual standard error of model.

+ Model was estimated with variables in first differences (N=51).

Table 12 notes (continued).

* Gun effect significant at p<=.10 level.

Table 13. Bimonthly Time Series Regressions of Gun Attack Fatality Rate on Measures of Gun Lethality (N=78)

Gun Measures	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Large Guns	.008 t=1.35					
Large Handguns		.009 t=1.54				
Semis			.01 t=2.32*			
Semi Handguns				.009 t=2.45*		
Large Semis					.01 t=2.59*	
Large Semi Handguns						.01 t=2.55*
Other Model Parameters:						
μ	2.14	2.16	2.35	2.38	2.50	2.52
time trend	-.01	-.01	-.01	-.01	-.01	-.01
season1	-.09	-.09	-.09	-.09	-.08	-.08
season2	-.17	-.16	-.18	-.17	-.16	-.16
season3	-.34	-.34	-.34	-.34	-.34	-.34
season4	-.22	-.22	-.22	-.22	-.21	-.21
season5	-.14	-.14	-.16	-.15	-.15	-.14
Q	14.39 df=18 p=.71	13.34 df=18 p=.77	13.77 df=18 p=.74	13.90 df=18 p=.74	12.18 df=18 p=.84	12.41 df=18 p=.83
SE	.147	.146	.143	.143	.142	.142

μ Denotes constant term. Q Denotes Ljung-Box chi-square statistic for residual autocorrelation (calculated at the 18th lag). SE Denotes residual standard error of model.

Season1=Jan.-Feb., Season2=Mar.-Apr., etc. Season6 (Nov.-Dec.) was ommitted as reference category. In all models, time trend and season2 through season5 terms were significant at p<=.05.

* Gun effect significant at p<=.05.

Table 14. Quarterly Time Series Regressions of Gun Attack Fatality Rate on Measures of Gun Lethality (N=78)

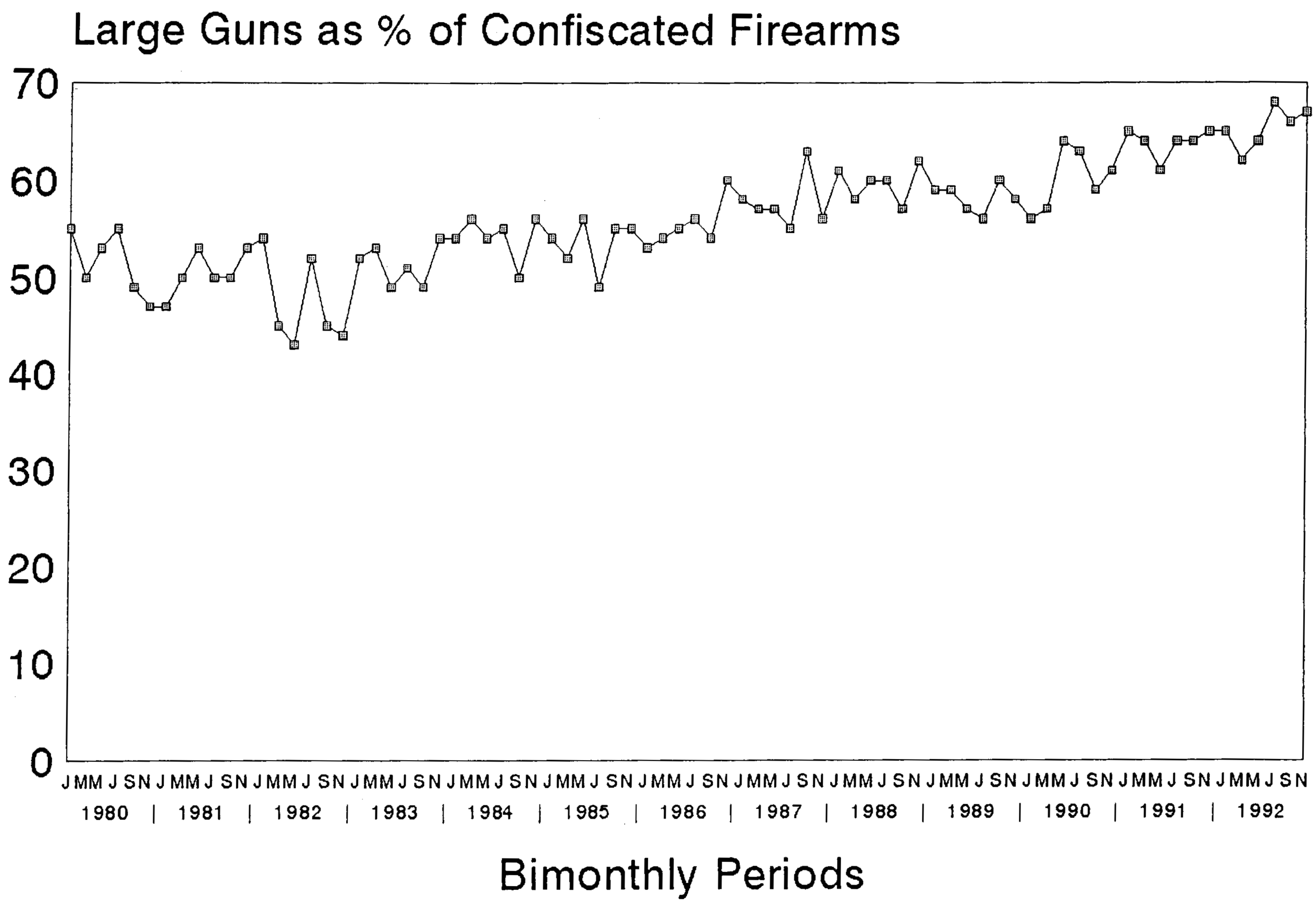
Gun Measures	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Large Guns	.009 t=1.08					
Large Handguns		.008 t=1.05				
Semis			.009 t=1.76*			
Semi Handguns				.009 t=1.94*		
Large Semis					.009 t=1.69*	
Large Semi Handguns						.008 t=1.76*
Other Model Parameters:						
μ	2.05	2.11	2.29	2.32	2.43	2.45
time trend	-.02	-.02	-.02	-.02	-.02	-.02
season1	-.04	-.03	-.03	-.03	-.03	-.03
season2	-.23	-.23	-.23	-.23	-.23	-.23
season3	-.11	-.11	-.11	-.11	-.11	-.11
Q	12.34 df=12 p=.42	12.50 df=12 p=.41	14.10 df=12 p=.29	13.64 df=12 p=.32	12.83 df=12 p=.38	12.97 df=12 p=.37
SE	.141	.141	.138	.137	.138	.138

μ Denotes constant term. Q Denotes Ljung-Box chi-square statistic for residual autocorrelation (calculated at the 12th lag). SE denotes standard error of model.

Season1=Jan.-Mar., Season2=Apr.-Jun., etc. Season4 (Oct.-Dec.) was ommitted as reference category. In all models, time trend, season2, and season3 terms were significant at p<=.05.

* Gun effect significant at p<=.10.

Figure 1: Large Guns
Dallas, TX, 1980-1992



Large Guns = Shotguns, Centerfire Rifles, and Handguns Greater Than .32 Caliber

Figure 2: Semiautomatic Guns
Dallas, TX, 1980-1992

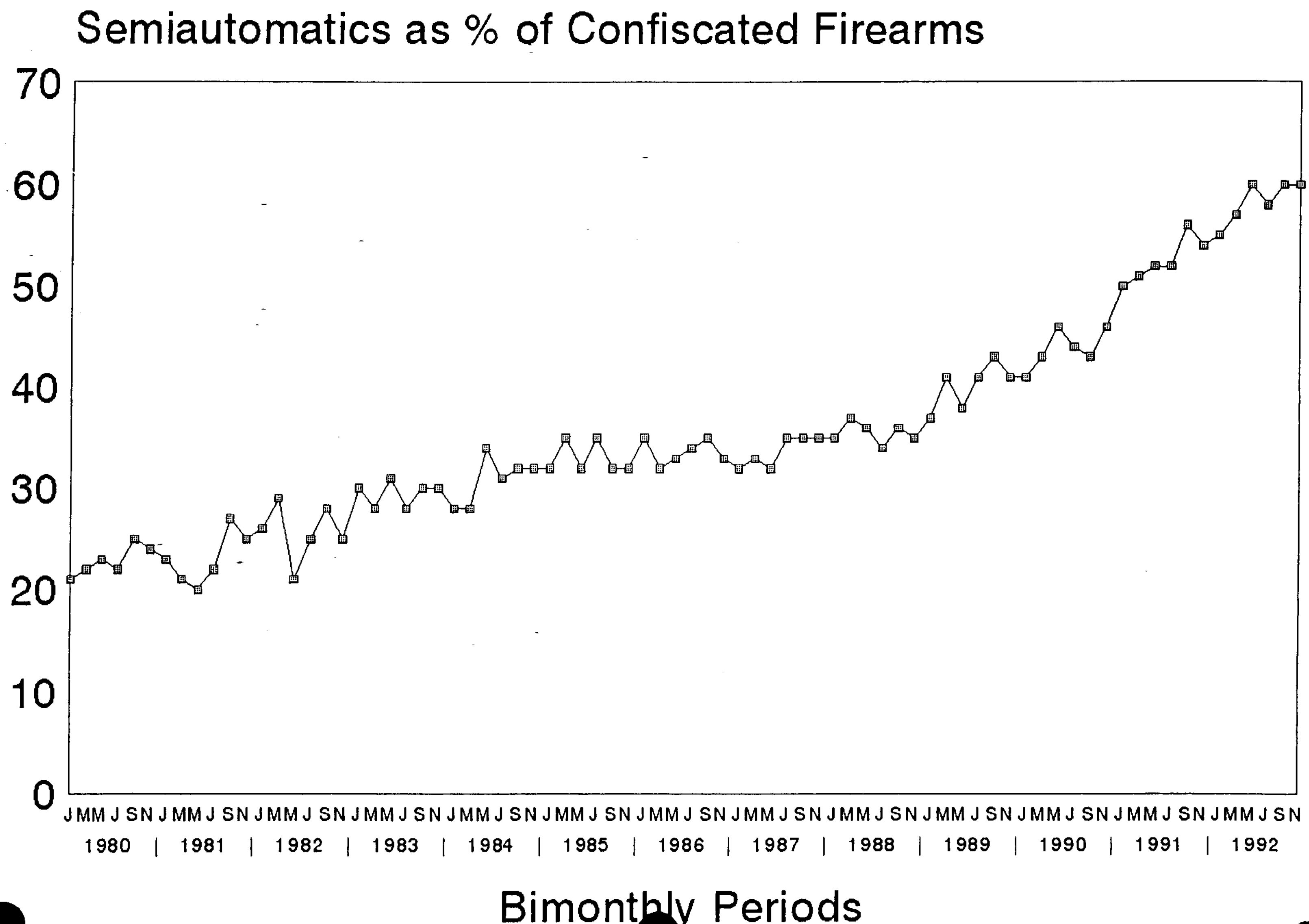
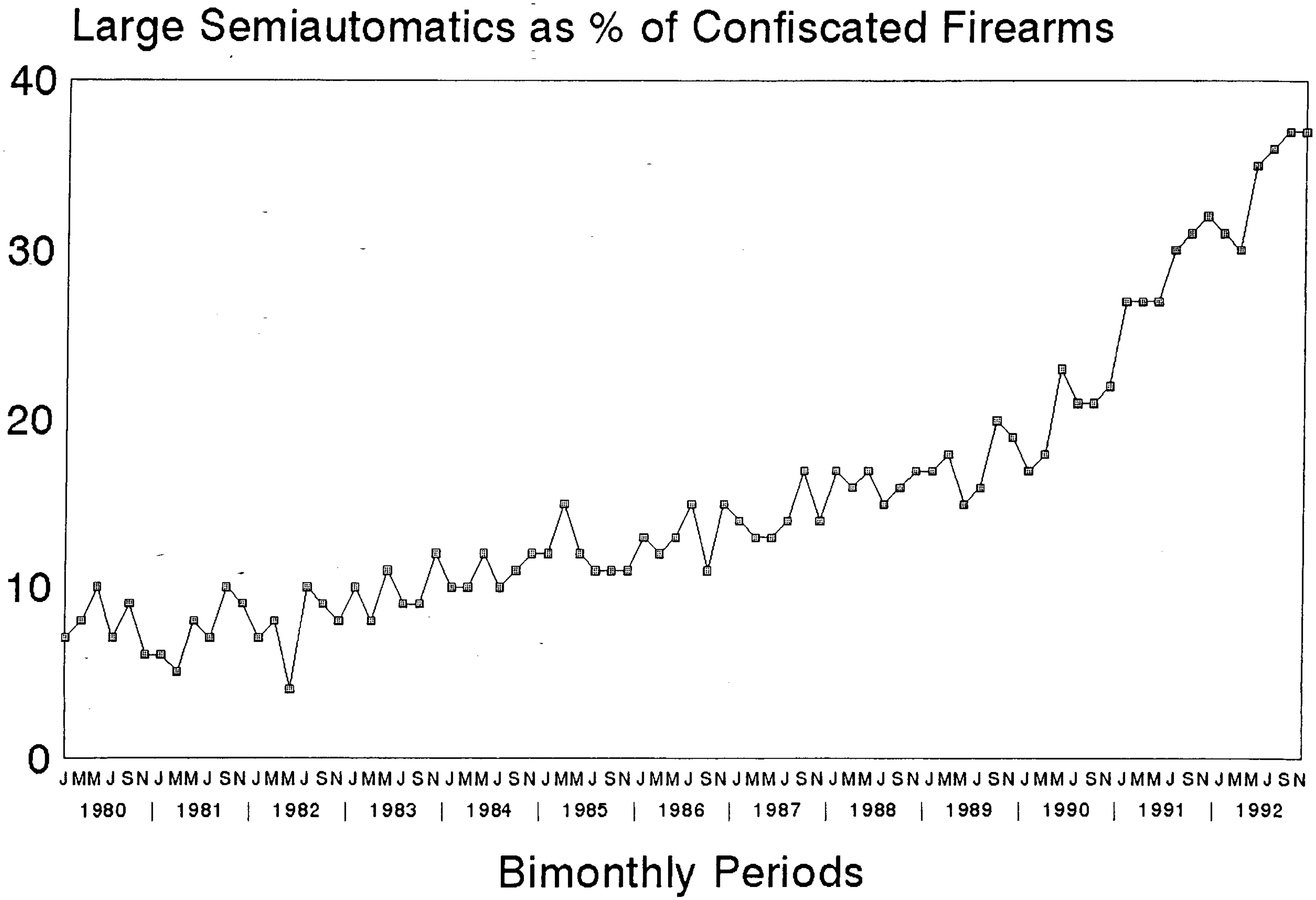
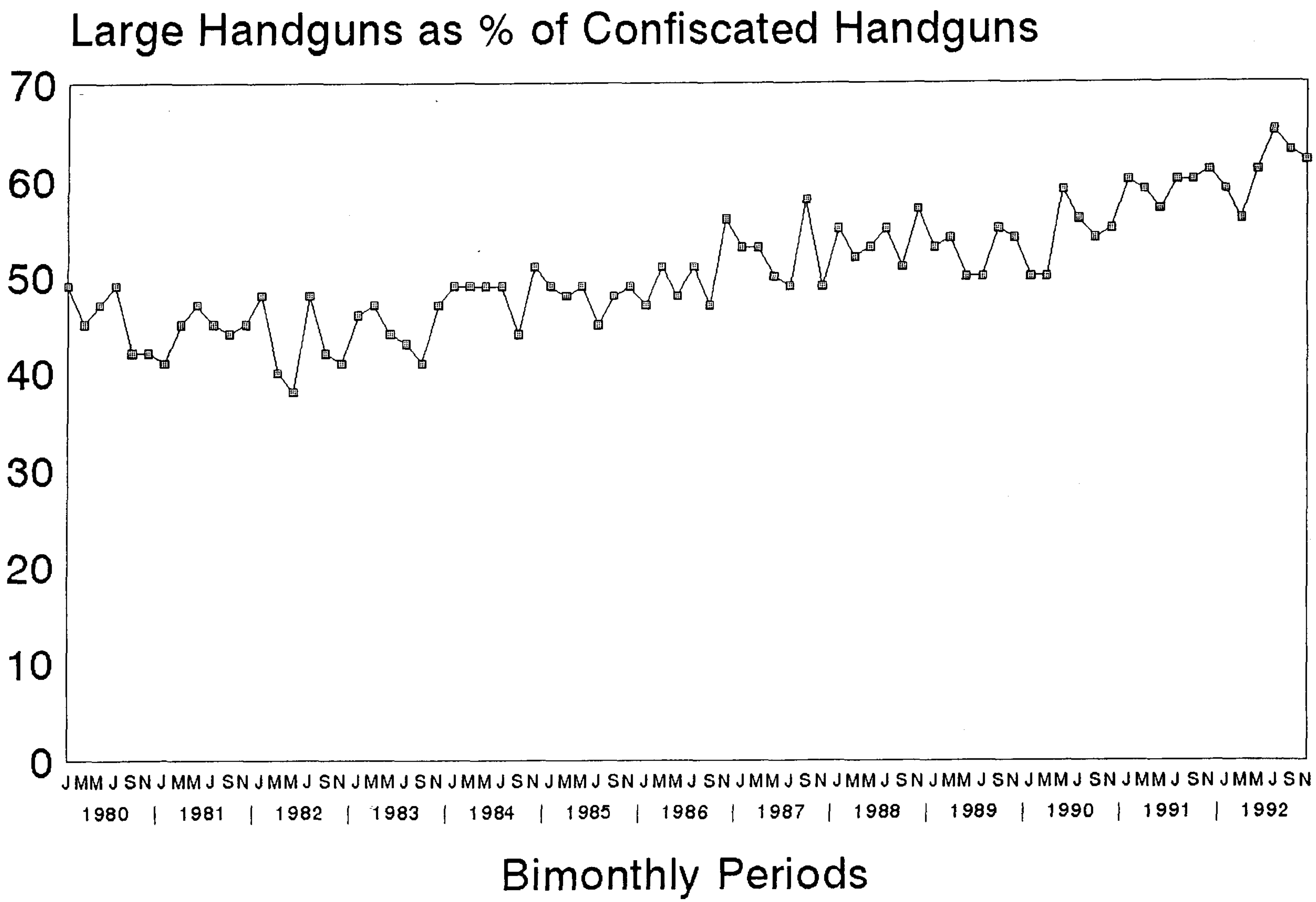


Figure 3: Large Semiautomatic Guns
Dallas, TX, 1980-1992



Large guns = shotguns, centerfire rifles, and handguns larger than .32 caliber.

Figure 4: Large Handguns
Dallas, TX, 1980-1992



Large handguns = handguns larger than .32 caliber.

Figure 5: Semiautomatic Handguns
Dallas, TX, 1980-1992

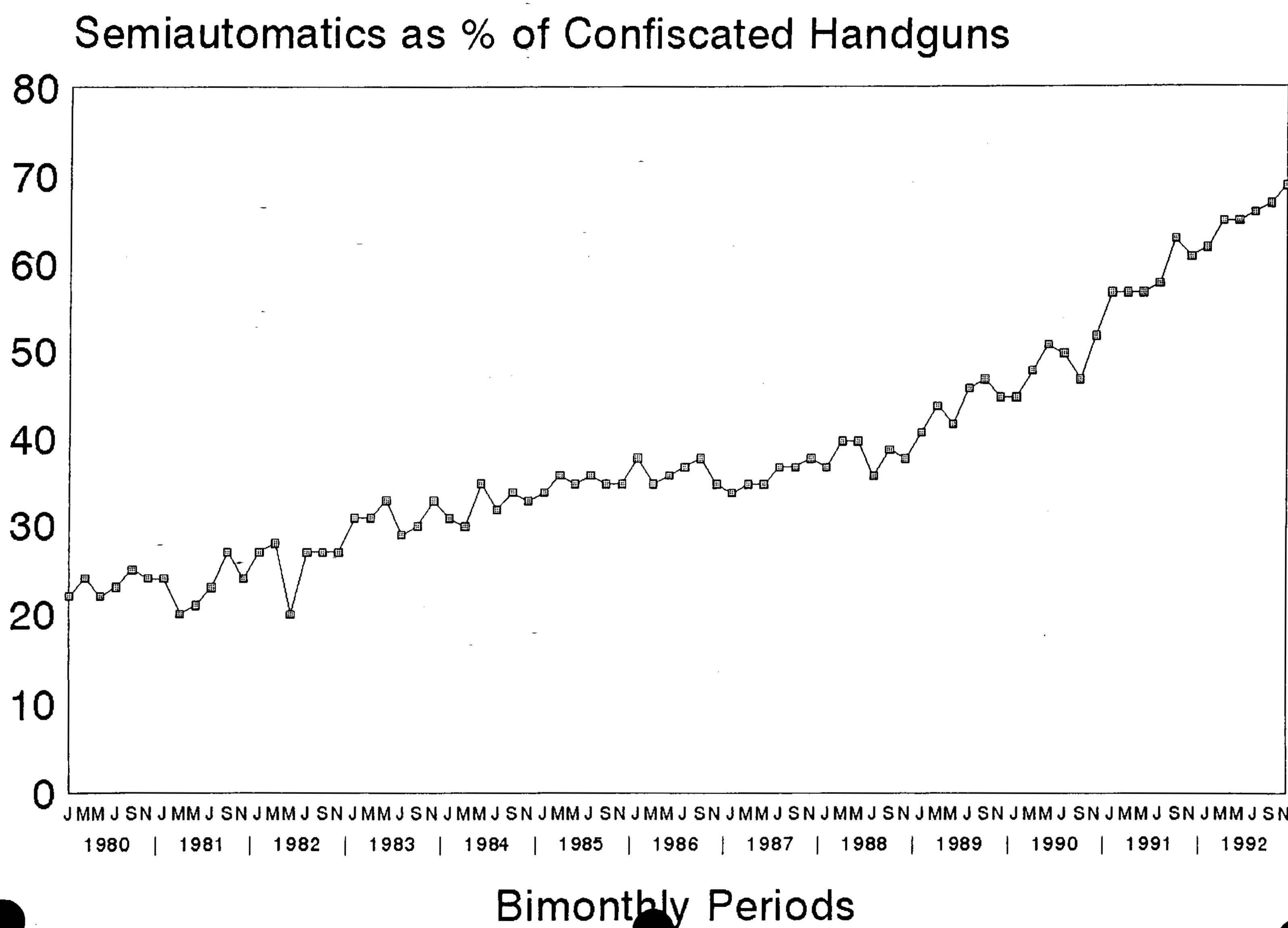
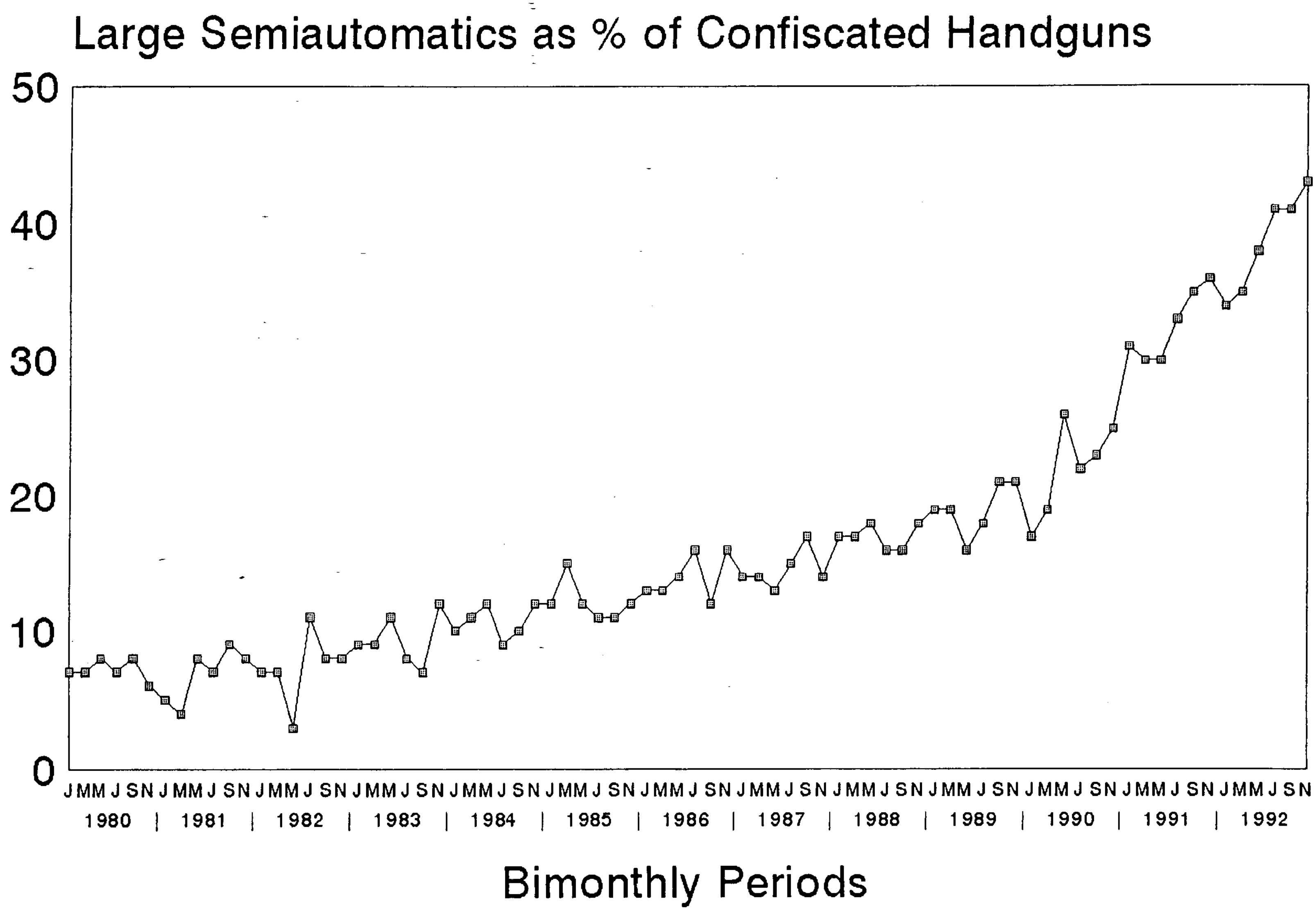
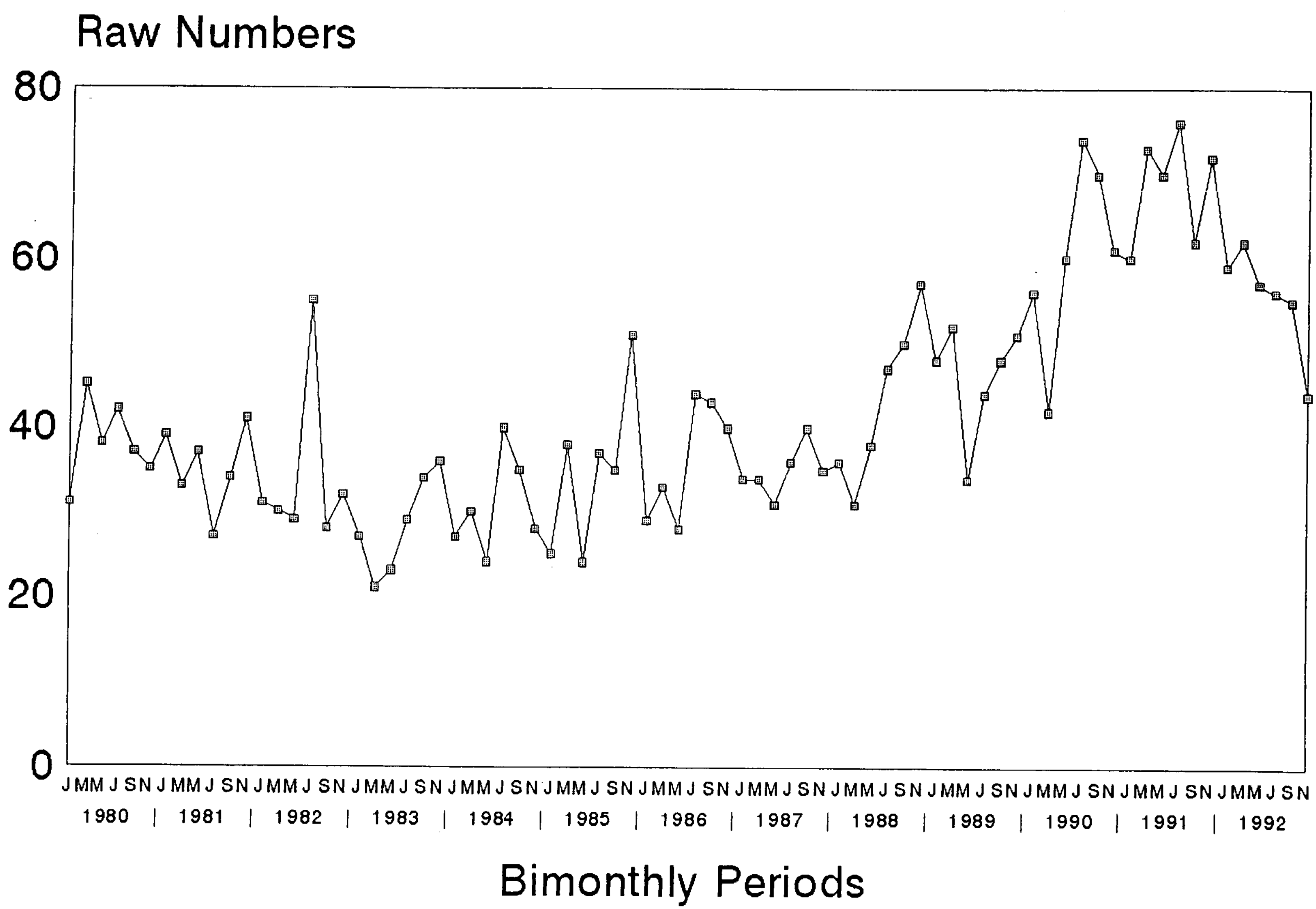


Figure 6: Large Semiautomatic Handguns
Dallas, TX, 1980-1992



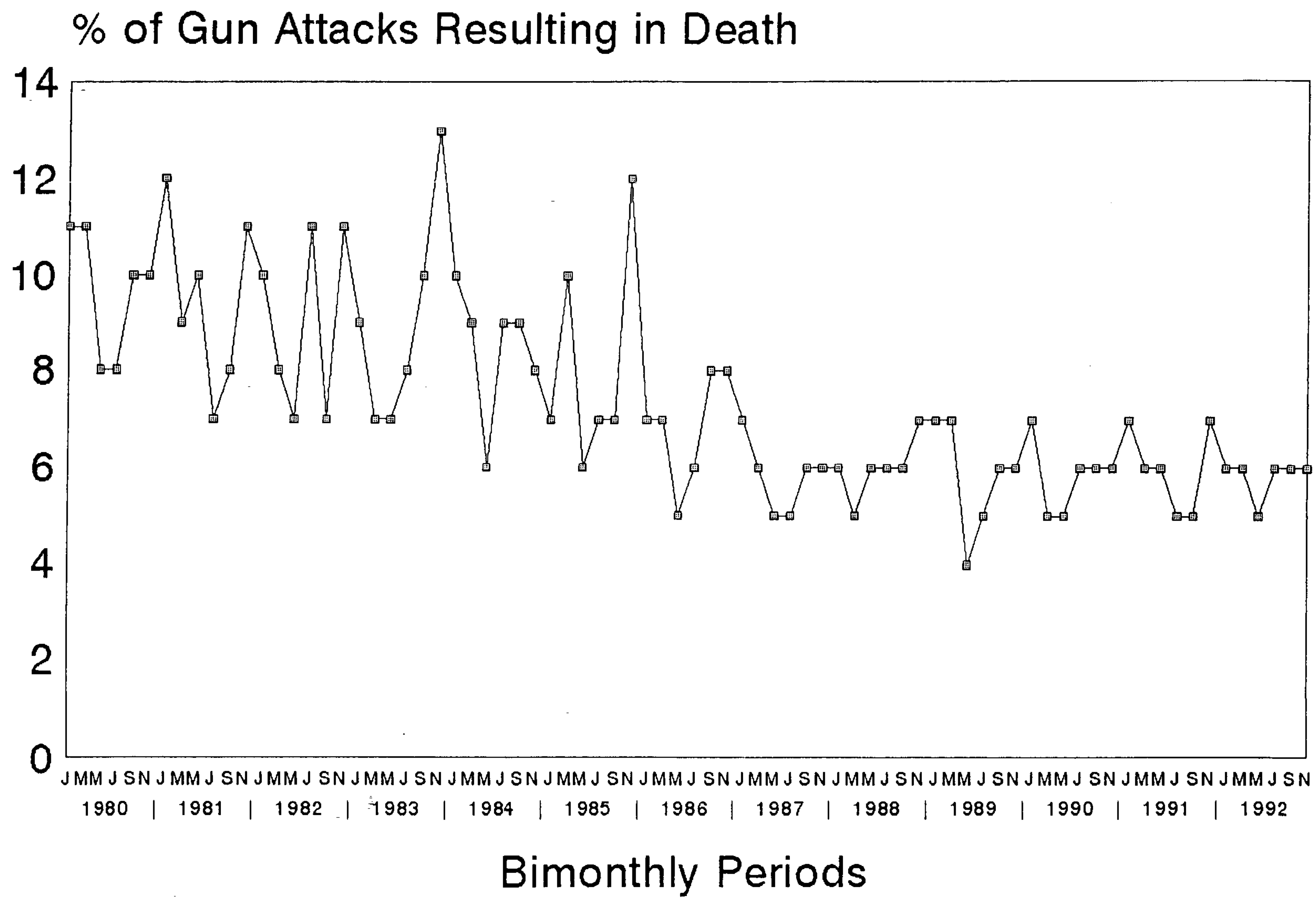
Large handguns = handguns larger than .32 caliber.

Figure 7: Gun Homicides
Dallas, TX, 1980-1992



Excludes justifiable homicides and negligent manslaughters.

Figure 8: Fatality Rate of Gun Attacks
Dallas, TX, 1980-1992



Gun attacks = gun homicides + gun aggravated assaults

Figure 9: Gun Density
Dallas, TX, 1980-1992

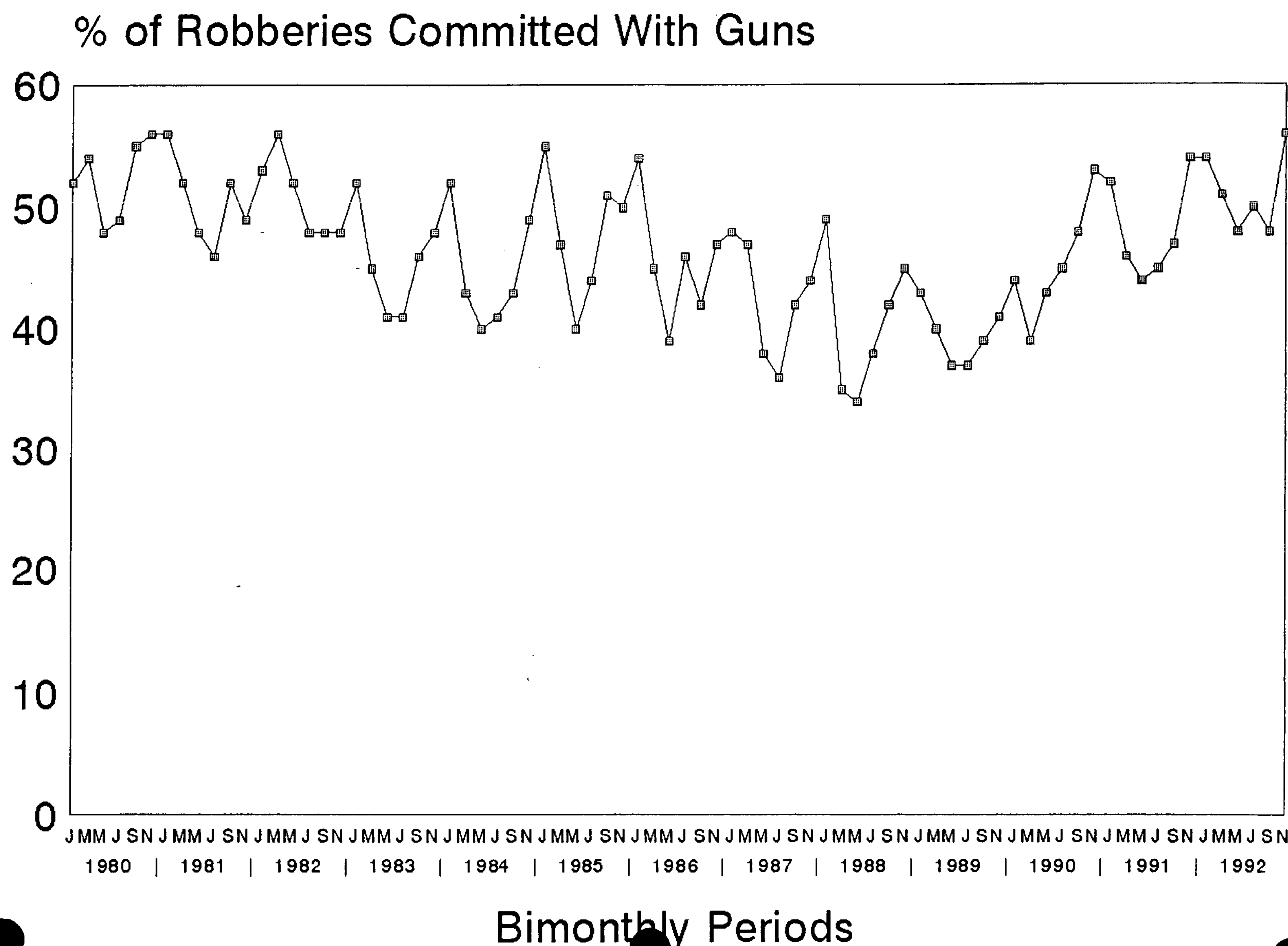


Figure 10: Gun Robberies
Dallas, TX, 1980-1992

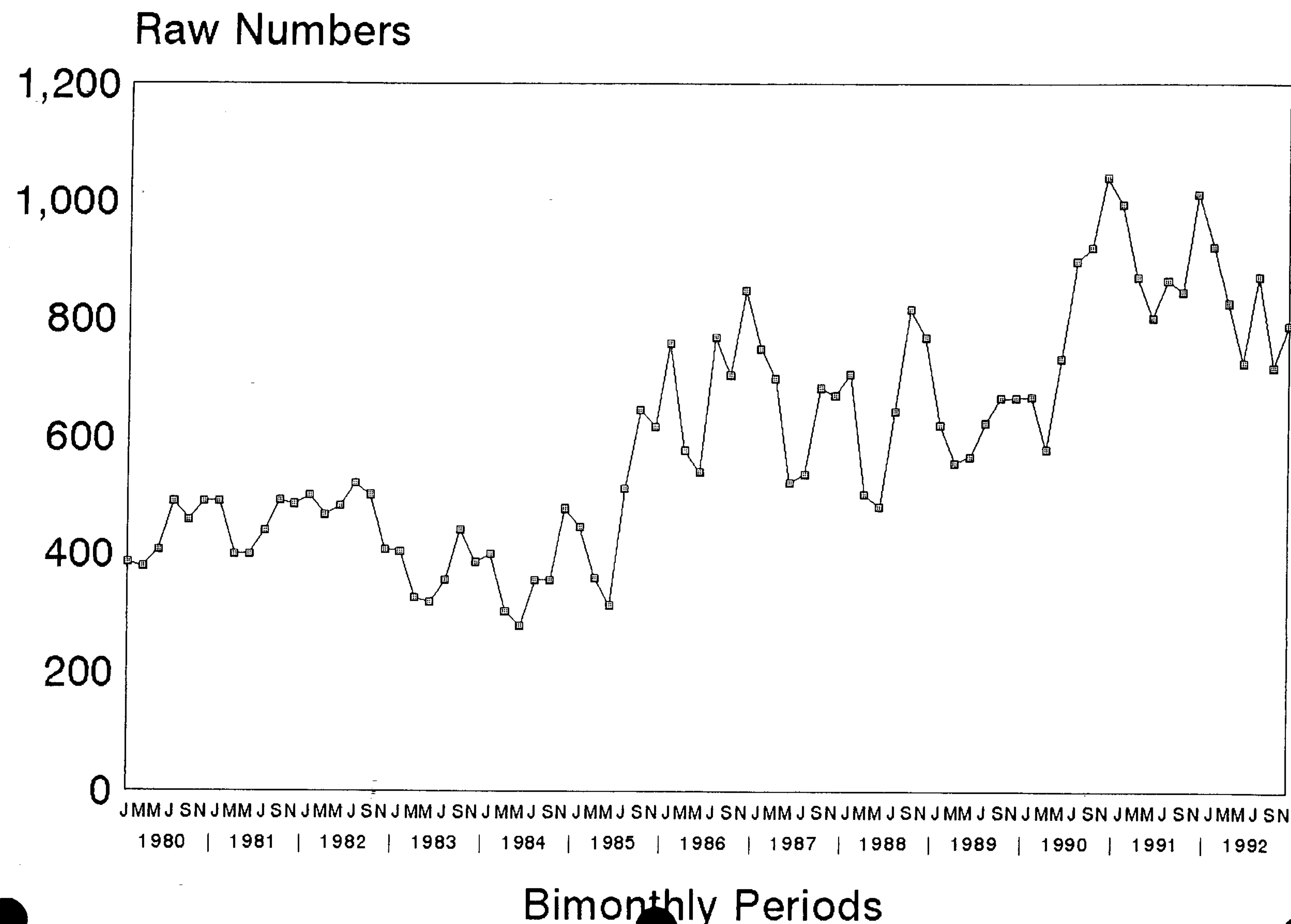


Figure 11: Total Robberies
Dallas, TX, 1980-1992

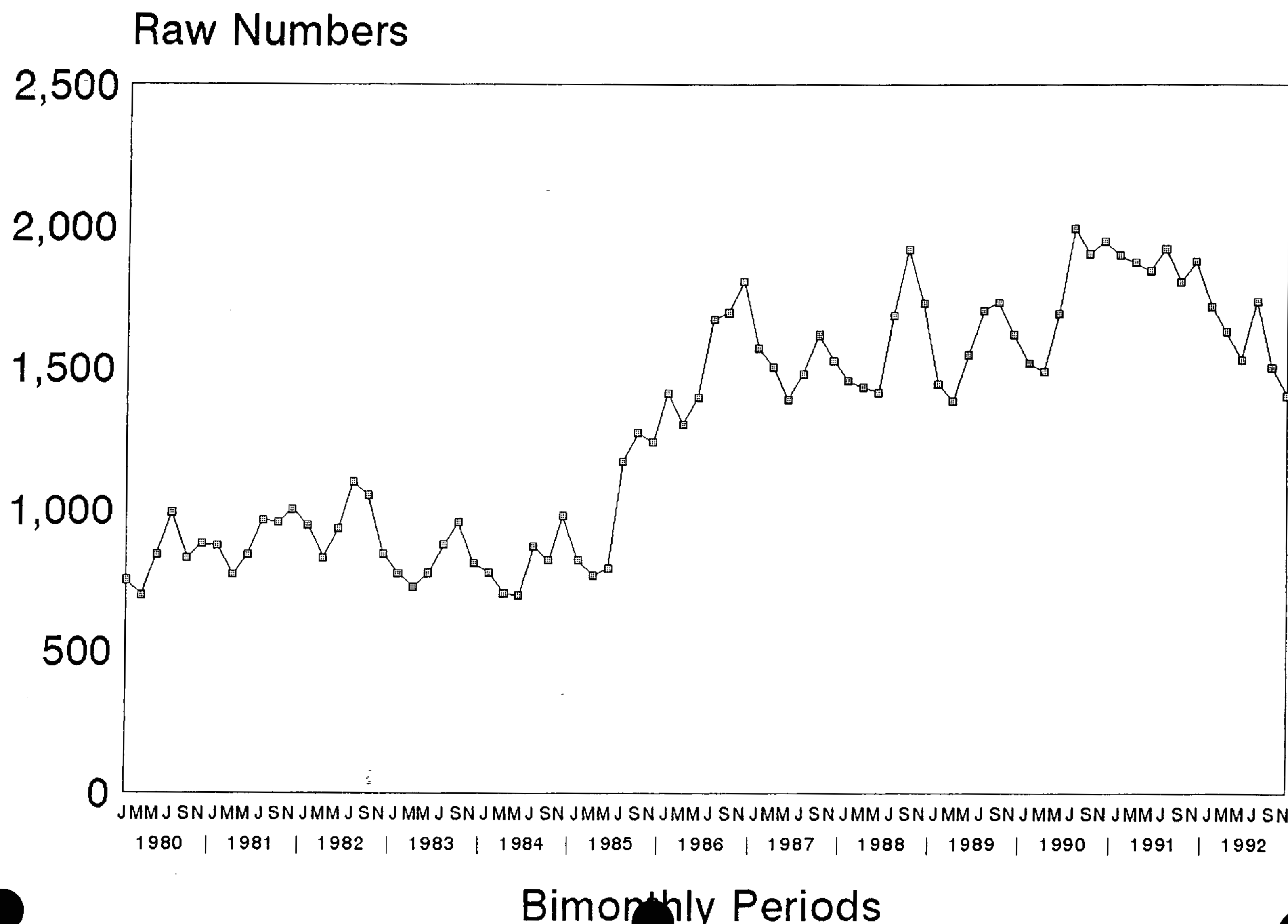
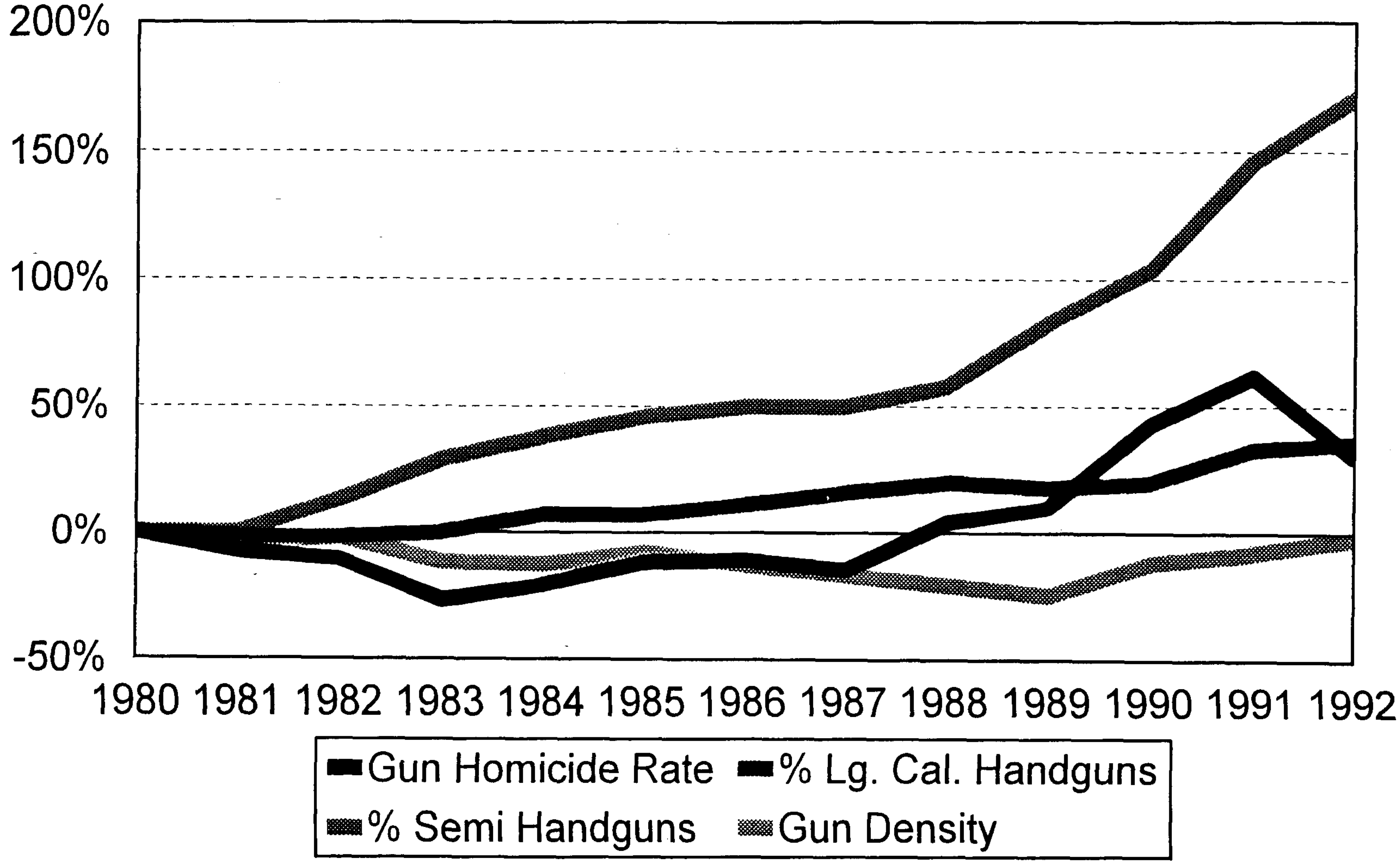


Fig. 12: Changes in Gun Lethality, Gun Density, and Gun Homicides
Dallas, TX, 1980-1992



Percent Changes Relative to 1980 Levels

APPENDIX A. KEY FIREARM TERMS

For this discussion, it is assumed that the reader understands what a firearm is and understands the difference between handguns and long guns. Other key terms are defined below.

Automatic: Weapons which fire continuously as long as the trigger is held down and ammunition remains (e.g., machine guns). Machine guns fire rifle caliber ammunition while submachine guns fire handgun caliber ammunition (Kleck 1991, p. 67).

Barrel: The steel tube of a firearm through which the bullet travels towards its target (Steindler 1970, p. 20).

Caliber: Technically, caliber is defined as the "bore diameter of a rifled barrel, usually measured from land to land" (Steindler 1970, p. 52). Essentially, this refers to the diameter (in inches or millimeters) of a firearm's barrel. The larger a firearm's caliber, the larger the ammunition it fires.

Centerfire: A cartridge with primer located in the center of the base of the cartridge (DiMaio 1985, pp. 16-17). Centerfire cartridges propel bullets at higher velocities than do rimfire cartridges.

Magazine: "A device for storing ammunition in a rifle, shotgun, or semiautomatic pistol" (Steindler 1970, p. 148).

Magnum: Magnum ammunition have larger cartridges with more gunpowder per round, thus giving them higher velocities than non-magnum ammunition. (This generalization is entirely true for shotgun ammunition [see DiMaio 1985, p. 168]).

Revolver: "A repeating handgun employing a revolving cylinder that moves cartridges (most commonly five to nine) into alignment with the barrel" (Kleck 1991, p. 66). Single action revolvers require the shooter to manually cock the gun (i.e., pull back the hammer) before each shot. Double action revolvers cock the hammer as the trigger is being pulled.

Rifle: "A long gun with a rifled barrel (spiraling grooves on the inside of the barrel); most rifles fire a single bullet with each trigger pull. Cartridges can be fed into firing position by movement of a hand-operated bolt, lever, or pump after each shot, or fed by a semiautomatic mechanism" (Kleck 1991, p. 67).

Rimfire: A cartridge with primer located around the rim at the base of the cartridge (DiMaio 1985, pp. 16-17). Rimfire cartridges propel bullets at lower velocities than do centerfire cartridges.

Semiautomatic: Rifles, shotguns, or handguns which fire one shot for each pull of the trigger. "Upon pulling the trigger, the gun fires, ejects the fired case, cocks the firing mechanism [i.e., the gun automatically cocks the hammer for refiring], and feeds a fresh round from the magazine. The trigger must be released between shots" (Steindler 1970, p. 20). Semiautomatics are also called autoloaders. Semiautomatic handguns are often referred to as pistols.

Shotgun: "A long gun with one or two barrels, each of which is smooth on the inside and fires a shotshell, discharging a large number of round pellets (usually from 15 to over 400), or sometimes a single large rifled slug. Ammunition can be chambered by operating a pump action for each round, by a semiautomatic mechanism, or the gun may have one or two barrels each of which holds one shotshell. Most hunting shotguns hold 2-5 rounds [and] most 'military and police' shotguns hold 5-9 rounds" (Kleck 1991, p. 67).

APPENDIX B: GUN DATA QUALITY AND CONSTRUCTION

As discussed in the main report, this study was conducted using data on all firearms confiscated by Dallas police during the study period, with the exception of gun records which had to be removed due to problematic or missing data. This technical appendix describes the work which was done to ensure the quality of the data and to prepare the gun data for analysis. The relevant items extracted from the Dallas Police Department's property inventory system were the NCIC (U.S. Federal Bureau of Investigation National Crime Information Center) code corresponding to the firearm's type (e.g., revolver, semiautomatic pistol, pump-action rifle, semiautomatic rifle, etc.), the caliber or gauge of the firearm, a property invoice number, the service incident number corresponding to the confiscation, and the date of the confiscation. We also made limited use of a narrative description field from the property system. This description field is maintained separately from the weapon type and caliber designations and provides a narrative description which contains information on one or more of the following elements: weapon type and caliber, manufacturer, model, barrel length, color, and/or other special features (e.g., folding stock, rusted gun).

B.1. Firearm Characteristics

In general, one would expect that police gun confiscation data are highly reliable with respect to general weapon type identifications (e.g., revolver, semiautomatic pistol, pump-action rifle, semiautomatic rifle, etc.) and caliber designations. Weapon types are relatively easy to recognize, particularly for experienced gun handlers, and calibers are often printed on the weapon and/or the ammunition. Previous work by Koper (1995) also indicated that police data are very accurate with respect to these basic dimensions of confiscated firearms.

The accuracy of the Dallas data with respect to weapon type and caliber was assessed in a number of ways, each suggesting that the gun data are highly reliable. The tests described below were performed on a master property room database which contained 80,472 records corresponding to firearms confiscated from the spring of 1978 through the spring of 1994.[1]

Virtually all of the records contained caliber/gauge designations and NCIC weapon type codes. Less than 1% of the guns had missing or obviously invalid (i.e., non-existent) NCIC weapon type designations.[2] In a few instances, the author recoded relatively small numbers of records corresponding to categories of weapons which, based on available narrative descriptions in the database, appeared to represent systematic miscodes.[3] After this initial inspection, the author removed records for air (or CO_2) guns, blank guns, flare guns,

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[1]At a later time, the author received an updated database which contained several hundred guns confiscated during 1992 which were not recorded in the original database. The new database also contained records on guns confiscated between the spring of 1994 and the fall of 1995. A less intensive examination of these records suggested that their quality was as high or higher than that of the records in the original database.

[2]An NCIC weapon code is a two character code. The first character provides the most general weapon type categorization, e.g., handgun, rifle, shotgun, grenade, etc. The second character provides further descriptive information about the operation of the weapon, such as whether a gun is a semiautomatic. An example of an invalid code would be a weapon designated as a "rifle, derringer." These codes are in conflict with one another because a derringer is a type of handgun. For each year used in the final analysis (1980-1992), 1% or less of the records had invalid weapon type codes.

[3]Most notably, approximately 160 records had the code "shotgun, derringer." Examination of available descriptive information suggested that these guns were actually double barrel shotguns.

toy guns, and other miscellaneous codes corresponding to weapons other than handguns, rifles, or shotguns.

The weapon type codes were then crosstabulated by the caliber/gauge designations to estimate the fraction of records having problematic weapon type-caliber/gauge combinations. An example would be a handgun coded as having .12 caliber. As far as the author can determine, there are no real .12 caliber handguns. Such a case would probably represent a miscoded .22 or .32 caliber handgun, or perhaps a shotgun with an incorrect weapon type code. The estimates were calculated by comparing the handgun and rifle calibers and shotgun gauges from the data to those listed in several literary sources (Gun Trader's Guide 1994; Hogg 1978; Murtz 1994; Quertermous and Quertermous 1993; Shooter's Bible 1994; Steindler 1970; Warner 1995). One percent or less of the handguns and shotguns had obviously invalid calibers. For rifles, the error rate was approximately 6%. However, 80% of the questionable rifle records had apparent shotgun gauges (e.g., .12, .20, .410), suggesting that these records were shotguns or rifle/shotgun combination guns which were miscoded.[4] Make and model descriptions, where available in the data, generally confirmed this, so these weapons were recoded as shotguns. After adjusting for these records, only 1% of the rifles appeared to have invalid calibers.

In addition, a series of crude reliability tests were run with groups of weapons made by selected manufacturers. To illustrate, if a particular handgun manufacturer makes only semiautomatic handguns, one can examine all guns in the database made by that manufacturer and determine what percentage were coded as weapon types other than

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[4]Though there may be a few rifles which fire rifled slugs of these sizes, it seems most likely that the records represent the types of coding errors mentioned above.

semiautomatic handguns. If 5% of the guns produced by this manufacturer have improper weapon type codes, then the manufacturer and/or weapon type must be incorrect for that 5% of cases. Similar tests are possible based on combinations of manufacturer (and, in some cases, model) identification, weapon type, and caliber.

Tests of this nature were conducted with various selected guns produced or distributed by 10 different manufacturers. A caveat to these tests is that they could only be conducted with guns for which the gun manufacturer was identified. This information was recorded in the narrative description field mentioned previously. Information in the narrative description field was not saved consistently in the Dallas Police Department's historical (i.e., long term) data files prior to 1988. For years prior to 1988, this information was not retrievable for anywhere from a quarter to nearly 100% of the records. Consequently, the tests focused disproportionately on recent year records.

The results are discussed in more detail in the last section of this appendix. In general, the tabulations revealed error rates of 5% or less. These estimates may be overestimates of true weapon type and caliber errors because those inconsistencies which did appear could have been due to incorrect manufacturer and/or model identifications. In previous work with gun data from another city, the author found indications that manufacturer/model identification errors are more common in police gun confiscation data than are errors concerning weapon types and calibers (Koper 1995). Further, some of the true caliber and weapon type errors may have had no consequence for the analysis because the weapons were later grouped into broad semiautomatic/non-semiautomatic and large/small caliber categories.

For example, a .22 caliber handgun mistakenly recorded as a .25 caliber would not have impacted the gun measures; either way, the gun would have been counted as a small caliber weapon. Similarly, a revolver mistakenly coded as a derringer would still have been counted as a non-semiautomatic.

Nevertheless, none of the aforementioned tests could ensure that individual guns were coded correctly. As a final test, therefore, 100 records were randomly sampled from among those entries having any narrative descriptive information. These records were examined for consistency between the codes in the weapon type and caliber fields and the weapon type and caliber information (if any) contained in the narrative description field. Records listing the make and model of the gun were cross-checked against gun catalogs (see those cited above and Fjestad 1994) to provide some external validation of the data.[5] Only 2% of the records had signs of obvious errors, providing further evidence that the data contained only random error with respect to weapon type and caliber designations.[6]

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[5]In cases for which only a gun manufacturer was listed, the author confirmed that the manufacturer at least made guns of that particular type and caliber. However, the listed manufacturers did not all appear in the reference gun catalogs. Hence, some records could not be externally validated with make and model data. Such cases were not counted as errors unless they contained inconsistencies between the weapon type and caliber codes and the narrative descriptions.

[6]Prior to creating the final time series gun databases, approximately 4,800 records were removed from the master database because they appeared to represent duplicate records of the same gun confiscations, i.e., they represented the same gun and seizure incident combination. (Multiple records corresponding to the same gun were not considered to be problematic if they represented seizures of the same weapon at different points in time. The problematic multiple records appeared to have resulted from nuances in the data entry process.) These records were primarily in the early years of the database. For the years of 1978 through 1986, estimates of duplicate records by year ranged from 5% to 31% of the firearm records having valid weapon type information. Years after 1986 appeared to have duplicate record rates of 1% or less, with the exception of 1989 which

B.2. Dates of Seizure

A key piece of information for time series analysis with these data is the date of confiscation. Written operating procedures of the Dallas Police Department require that officers assign property tags to firearms at the time they are confiscated. These tags are dated, and the dates are stored in the Department's information system. However, confiscation dates were not saved consistently in the Department's long term records prior to 1988. Though the large majority of records were saved with an indicator for the year during which the firearm was seized, the exact date of confiscation was missing for a substantial percentage of pre-1988 records. On a yearly basis, rates of missing date information ranged from an estimated 25% to nearly 100% for the 1978-1987 period, with the highest missing rates corresponding to the earliest years. After the first three months of 1988, virtually all records were saved with confiscation dates.

Fortunately, the approximate period of confiscation could be estimated for the majority of the early year records, based on an inspection of the service incident numbers of those records having

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had a rate of 2.6%.

Counts and subsequent screens for duplicate records were approximations (particulars of the data structure and missing data elements made it impossible to produce exact counts and screens). Consequently, a small number of duplicate records may have remained in the data after the screening procedure; conversely, a small number of valid gun records may have been removed by the screening procedure. Nonetheless, a manual inspection of records with descriptive information from the early years of the database suggested that any such errors were very rare (1% or less of records).

The tests of weapon type and caliber fields which were described in the previous section were conducted before the screens for duplicate records. Though the author did not systematically rerun all of those data checks after screening for duplicate records, subsequent work with the data did not alter the conclusions regarding data quality. For instance, the percentage of records which had to be excluded due to problematic weapon type codes was still less than 1% after screening the data for duplicate records.

dates. As a general rule, service incident numbers in the property system ascend with confiscation dates. By examining the service incident numbers of dated gun records near the beginning and ending of particular periods, it was possible to estimate which service incident numbers were assigned during those periods and, accordingly, which guns were confiscated during those periods. This could be accomplished with more accuracy and with less remaining missing data by using larger time aggregations. In order to balance these concerns with the need to have sufficiently long time series for ARIMA modeling, the data were aggregated at bimonthly and quarterly intervals. An added advantage to using bimonthly and quarterly time points is that they arguably provide more robust gun measures which are less sensitive to random events (such as drug busts which might produce large caches of weapons) that might conceivably distort the gun measures.

Nevertheless, the bimonthly and quarterly periods of confiscation could not be accurately estimated for all of the firearms. Only six records had confiscation dates corresponding to 1978, so no attempt was made to estimate dates for guns seized during that year. Further, bimonthly dates could not be assigned to a little over a quarter of the guns seized during 1979. As a result, the 1978 and 1979 data were excluded from the analysis. Data were retained for the years 1980 onward. However, the author was unable to assign bimonthly dates to an estimated 15% of the guns confiscated during 1980. For the years 1981 through 1983, an estimated 5% to 10% of the records could not be assigned to bimonthly periods. This figure dropped to 2% to 3% for 1984 and 1985. From 1986 onward, 1% or less of the records could not be grouped into bimonthly periods. When the data were aggregated on a quarterly basis, the rates of missing date information were lower for each year.

Although the remaining missing data rates were less than ideal for the early years of the database, this does not present any obvious problems because this investigation focuses on the characteristics of the guns rather than their numbers, and there is no reason to believe that the guns excluded from the time series analysis due to this problem differed systematically from the other guns. The excluded guns tended to have been confiscated near the end of one month and the beginning of the next.[7] In the absence of any reason to suspect that guns seized at the beginning or ending of a month are different in terms of weapon types and calibers from those seized at other points in the month, it seems reasonable to treat this problem as a random source of error.

B.3. Construction of Firearm Time Series Data

Subsequent to the adjustments described in the preceding sections, the gun data were aggregated into bimonthly and quarterly databases covering the years 1980 through 1992.[8] The time series databases contain several fields corresponding to semiautomatic and non-semiautomatic firearms of various calibers and gauges. Several different handgun caliber fields were created so that future

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[7]To provide an illustration with bimonthly periods (Jan. through Feb., March through April, etc.), the last dated record for February of year X may have been February 20, and the first dated record for March may have been March 15. Guns falling in between those dates could not be ascribed to either period with certainty, and such guns would have been excluded from our time series databases.

[8]The 1993-1995 firearm data were not utilized for this study because Supplemental Homicide Report and Uniform Crime Report data were not publicly available for those years at the time the final databases were constructed.

researchers may experiment with different gun lethality specifications. To simplify this process, the author chose only handgun calibers which appeared 30 or more times in the master database (these calibers represented more than 99% of the confiscated handguns). Separate counts were also created for shotguns of all gauges. The rifles were grouped into broad categories of .22 caliber versus all other calibers for reasons discussed in the main report.

The bimonthly database has 78 observations with aggregated information on 57,751 confiscated firearms. The quarterly database has 52 observations with information regarding 57,991 confiscated firearms (less cases were lost due to missing confiscation dates when the data were aggregated at larger time intervals). For the years 1984 through 1992, the data represent nearly 100% of the guns confiscated by Dallas police. For earlier years, the data represent approximately 85% to 95% of the records received from the Dallas Police Department.

One final caveat should be noted. The time series databases show an unusual drop in gun confiscations during 1982. To illustrate, bimonthly gun confiscations averaged 465 in 1981, 302 in 1982, and 487 in 1983. The drop in 1982 was due to unusually low numbers of guns for the spring and summer of 1982. The author consulted personnel in Dallas but was unable to determine whether this pattern represents a real drop in gun confiscations which occurred during 1982 or a data loss in the department's property inventory records.[9]

Other users of these data should be aware that the 1982 numbers in particular may not be an accurate representation of the number of

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[9]The data screening/construction procedures did not cause a disproportionately high loss of guns from 1982 relative to other early years in the original property database.

guns confiscated during that year. (In general, this is a caveat for all years prior to 1984). The focus of this study, however, is upon the characteristics of confiscated guns rather their numbers, and the gun data were used to approximate those characteristics. Gun lethality trends shown in figures 1 through 6 of the main report do not reveal any clear outliers in any of the gun series during 1982. Since there were no obvious distortions in the gun lethality series, no additional adjustments were made to the data.

B.4. Illustration of Data Accuracy Tests

Illustrated below are the tests for data accuracy which were conducted with records from the original gun-based property room file. The tests were based on tabulations of various weapon types, calibers, and manufacturers (see section A of this appendix). Note that the weapon types and calibers listed below may correspond to gun models which have been discontinued by the listed manufacturers. Also, the number of weapons identified for each manufacturer was approximate because spelling variations in the gun descriptions could have resulted in missing some weapons produced by these companies. Most of the tabulations involved handguns since they represent the majority of the confiscated guns. These tests were conducted in the latter part of 1995, and statements regarding the production of various guns are based on information available at that time. The primary reference sources used for these tests were Gun Trader's Guide (1994), Modern Guns: Identification and Values (Quertermous and Quertermous 1993), Guns Illustrated 1994 (Murtz 1994), and Gun Digest 1995 (Warner 1995).

1. Manufacturer: Glock. According to available catalogs, Glock

makes only handguns. All models are semiautomatics, and the available calibers are 9mm, 10mm, .45, and .40. There were 236 guns in the database which were identified as Glocks. All of these guns were coded as semiautomatic handguns, and all of them had calibers in the proper range.

2. Manufacturer: Taurus. According to the reference sources, Tauras makes only revolvers and pistols. Tauras revolvers are available in calibers .357, .44, .38, .32, and .22. Pistols are available in calibers .22, .25, .380, .40, and 9mm. Out of 1,442 Tauras guns in the data, 5 had invalid codes or codes corresponding to gun types not made by Taurus. Thus, the error rate was well under 1% (5/1,442 = .003). Less than 1% of both the revolvers and pistols had calibers outside the appropriate ranges.

3. Manufacturer: Wesson (also called Dan Wesson). This manufacturer makes only revolvers (a number of these are special competition handguns). Only 1 of the 191 Dan Wesson guns in the data had an inappropriate weapon type code. Wesson manufactures revolvers in a wide variety of calibers, and only 1 gun had a caliber outside the appropriate range.

4. Manufacturer: Beretta. This manufacturer makes handguns, rifles, and shotguns. The focus here is on handguns. Beretta makes only semiautomatic handguns. Approximately 1% of the 682 Beretta guns in the data had invalid or incorrect weapon type codes. Beretta makes handguns in a wide variety of calibers, and only two of the guns had calibers outside the appropriate range.

5. Manufacturer: Davis Industries. This manufacturer makes a number of pistols and derringers. Twelve of the 1,741 Davis guns in the data had incorrect weapon type codes, for an error rate under 1%.

In terms of caliber, 17 (or, 1%) of the guns had calibers not appearing among Davis guns listed in the reference catalogs. Looking separately at the pistols and derringers, 1% of the pistols had inappropriate calibers, while none of the derringers appeared to be in error.

6. Manufacturer: Llama. This manufacturer makes revolvers and pistols. Overall, less than 1% of the 722 Llama guns in the data had incorrect weapon type codes or incorrect calibers. Separate examination of the pistols and revolvers revealed that virtually none of the pistols had apparent caliber errors. Six (or 6%) of the 101 Llama revolvers had calibers appearing to be in error. However, inspection of these questionable cases suggested that some of them may have had inaccurate manufacturer information.

7. Manufacturer: Mossberg. There were 981 records corresponding to this manufacturer of rifles and shotguns. Overall, four (or, 0.4%) had an invalid weapon type code. To assess combinations of weapon type and caliber, semiautomatic rifles and semiautomatic shotguns were examined. Mossberg semiautomatic rifles come in only .22 caliber, and all of the 25 Mossberg semiautomatic rifles in the data were .22 caliber. There were only 4 Mossberg semiautomatic shotguns in the data, and all of these guns were in the proper gauge range (.12 or .20).

8. Manufacturer: Marlin. This manufacturer of shotguns and rifles appeared 527 times. Overall, eight of these guns, or 1.5%, had an obvious invalid or problematic weapon type code. Nearly 500 of the weapons were identified as rifles, and only 3 of these guns had calibers outside the appropriate range for Marlin rifles. One of the 32 identified shotguns had an apparently invalid gauge (3%). To

evaluate rifle caliber/weapon type combinations, we focused upon semiautomatic rifles. Marlin semiautomatic rifles are manufactured in .22, 9mm, and .45 calibers. Slightly under 1% of the 253 Marlin semiautomatic rifles in the data had calibers outside this range.

9. Manufacturer: Remington. This company manufactures rifles, shotguns, and a small number of handgun models. We focused upon the company's rifles and shotguns. Weapon type coding error rates were 1%. None of the 585 shotguns had gauges outside the appropriate range. About 2% of the rifles had apparently invalid calibers. Focusing on semiautomatic rifles, 6/170 = 3.5% appeared to have inappropriate caliber codes.

10. Manufacturer: Intratec. This company produces derringers and semiautomatic handguns. Some of the semiautomatic handguns produced by this manufacturer (e.g., the TEC-9 and the TEC-22) were banned from further production by the federal government's Violent Crime Control and Law Enforcement Act of 1994. Between 2 and 3 percent of the 694 Intratec guns in the data had inappropriate weapon type codes. (Most of the Intratec semiautomatic handguns were coded as submachine gun/machine pistols rather than semiautomatic handguns. This was likely due to the machine gun-style appearance of weapons like the TEC-9 and TEC-22. An earlier inspection of cases having the submachine gun/machine pistol classification revealed that these weapons were virtually all semiautomatic handguns, many of which resemble weapons like the TEC-9 and TEC-22. Therefore, these weapons were counted as semiautomatic handguns unless there was descriptive information identifying them as rifles. Consequently, Intratec guns labeled with the submachine gun/machine pistol code were not counted as errors.) Approximately 1% of the Intratec guns had calibers

outside the appropriate range.

APPENDIX C: ARIMA TIME SERIES METHODOLOGY

C.1. Overview of Time Series Processes

ARIMA time series modeling (also known as Box-Jenkins modeling or dynamic regression modeling) posits that a time series is a function of present and past inputs and outputs. In the context of univariate time series modeling, random shocks (a_t) are considered to be the major driving force behind an observed time series. These shocks represent any of a vast number of forces causing variation in a time series (random shocks are assumed to be independent and normally distributed with a mean of zero and a constant variance). A random shock influences the outcome of a time series at time t. Afterward, it may continue to exert influence on subsequent outputs, but its influence diminishes over time.

ARIMA models consider three different processes by which past inputs and outputs produce an observed time series. The first of these processes is an integrated process (McCleary and Hay 1980, pp. 36-45). In an integrated process, the effects of random shocks accumulate over time in an additive fashion. Each observation is equivalent to the previous observation and a current random shock. An integrated process does not have a stationary mean; instead, it trends or drifts. A trending time series moves systematically upward or downward. A drifting time series moves in an unpredictable fashion, moving in one direction for a time, then changing direction, then going back to its original direction, and so on. An integrated time series can be made stationary by differencing the time series. That is, the first observation is subtracted from the second observation, the second observation is subtracted from the third observation, and so forth. This is referred to as first-order differencing. According to McCleary and Hay, social science time series normally need to be differenced only once, if at all; higher order differencing is rare.

The second time series process is an autoregressive process (McCleary and Hay 1980, pp. 53-61). When an autoregressive process is operating, each observation consists of a current random shock and a portion of the preceding p observations. In other words, the current observation is a weighted sum of the preceding p observations. In this process, a random shock at time t continues to have an effect after time t, but its influence diminishes exponentially. Although in theory the effects of each shock continue infinitely, these effects are essentially zero beyond the length of p. Thus, with a first order autoregressive process, each observation is treated as a function of the previous observation and a random shock. If a second order autoregressive process is operating, each observation is modeled as a function of its past two observations and a random shock. This can be generalized to higher order processes, but such processes are more rare in the social sciences (McCleary and Hay 1980, p. 59).

Estimating an autoregressive model requires estimation of the effect which the preceding p observations have upon the current observation. Because the effects of the previous observations diminish over time, these coefficients must be fractions. For a first order autoregressive process, these coefficients (ϕ) are constrained to be between -1 and 1, referred to as the bounds of stationarity. The bounds of stationarity for a second order autoregressive process are (McCleary and Hay 1980, p. 60):

$$-1 < \phi_2 < +1$$
$$\phi_1 + \phi_2 < +1$$
$$\phi_2 - \phi_1 < +1.$$

The third time series process is a moving average process

(McCleary and Hay 1980, pp. 61-64). When a time series is characterized by a moving average process, each random shock has an effect which persists for only q observations before vanishing. Thus, a first order moving average process is characterized by random shocks whose effects last exactly one period after they occur. As with autoregressive processes, first order moving average processes are the most commonly encountered in social science data, though higher order processes are possible. The parameters of a first order moving average process are also constrained to be between -1 and 1. These are referred to as the bounds of invertibility for moving average parameters. For a second order moving average process, the bounds of invertibility for the moving average parameters (θ) are (McCleary and Hay 1980, p. 64):

$$
\begin{gathered}
-1 < \theta_2 < +1 \\
\theta_1 + \theta_2 < +1 \\
\theta_2 - \theta_1 < +1.
\end{gathered}
$$

Any or all of these processes may also operate on a seasonal basis. If, for instance, a time series has regular and seasonal first order autoregression, then each observation is dependent upon the preceding observation and the corresponding observation from the previous cycle (i.e., the previous year).[1]

Identification of the process generating a time series is made

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[1]The general ARIMA notation for a univariate model is ARIMA(p,d,q) where p refers to the autoregressive process, d refers to the order of differencing, and q refers to the moving average process. These processes may operate alone or in combination. An ARIMA(1,1,0) model, for instance, represents a time series which requires first order differencing and exhibits first order autoregression after differencing.

The full notation for an ARIMA model with seasonal effects is ARIMA(p,d,q)$(P,D,Q)_S$. The first p,d, and q represent the regular autoregressive, integrated, and moving average components, the second P, D, and Q represent the seasonal autoregressive, integrated, and moving average components, and S represents the length of the cycle (S would be 12 for monthly data, 4 for quarterly data, etc.).

empirically by calculation and examination of an autocorrelation function (ACF) and a partial autocorrelation function (PACF) (McCleary and Hay 1980, pp. 66-79). The autocorrelation function shows the correlations between the series value at time t and its past values, t-1, t-2, etc. The partial autocorrelation function shows the correlations between observation t and observations at k lags after controlling for the correlations of observation t and intermediate lags between t and k. The different time series processes described above produce theoretically distinct patterns in the ACF and PACF (see McCleary and Hay 1980, pp. 78-80,88-90). Although it is not always a straightforward task, the process generating a time series is identified by inspection of the ACF and PACF.

The values of the ACF are particularly important in identifying a time series process. The ACF coefficient for lag k begins with the expression:

$$\Sigma[(Y_t - Y_{mean})(Y_{t+k} - Y_{mean})] \,/\, \Sigma(Y_t - Y_{mean})^2$$

in which the numerator is summed over n-k observations and the denominator is summed over all n observations. This expression is then multiplied by n/(n-k) (McCleary and Hay 1980, p. 66). The standard error of ACF(k) is given by:

$$[1/n(1 + 2\ \Sigma\ ACF(i)^2)]^{1/2}$$

in which $\Sigma\ ACF(i)^2$ is the summation of the squared ACF coefficients up to lag k (McCleary and Hay 1980, p. 94).

In addition to evaluating the magnitude of individual ACF coefficients, a χ^2 statistic known as the Q statistic is commonly used to test whether the autocorrelations to lag k are, as a group, significantly different from zero. If a series has a constant mean and residuals which are normally distributed with a mean of zero and a constant variance (such a process is often referred to as a white noise process), the Q statistic should be statistically insignificant. The Ljung-Box Q statistic is represented by:

$$Q = n(n + 2)\ \Sigma[ACF(i)^2 / (n-k)]$$

in which the term $ACF(i)^2/(n-k)$ is computed and summed for all k lags (see Pankratz 1991, p. 50). This statistic is distributed approximately as a χ^2 with k degrees of freedom.

C.2. Regression with Time Series Errors

When using regression with time series errors, the analyst regresses the dependent variable on the independent variable(s) and then examines an ACF and PACF of the model residuals to determine if the residuals are correlated and, if so, what type of time series process characterizes this correlation (Pankratz 1991; Pyndick and Rubinfeld 1991).[2] If the ACF pattern matches that of an integrated process, it suggests that the residuals are not stationary (i.e., they do not have a constant mean). In this case, the analyst differences each variable in the equation and reestimates the model. If the ACF suggests seasonal non-stationarity, then the equation should be reestimated after differencing each variable seasonally.

Once the residuals are stationary, the analyst models any remaining autocorrelation as an autoregressive and/or moving average

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[2]The time series regression approach described here and used in this analysis requires the analyst to specify the nature of the relationship between the independent and dependent variables based on theoretical grounds. In other words, the analyst must specify whether the independent variable(s) has contemporaneous and/or lagged effects on the outcome measure. If the effects are lagged, the analyst must specify the proper lag structure. If there is uncertainty regarding the relationships, one may employ cross-correlation functions (McCleary and Hay 1980) or liner transfer functions (Pankratz 1991) to determine the proper lag structures.

process based upon the patterns in the ACF and PACF. The analyst selects and estimates a tentative model and calculates an ACF and PACF for the model residuals. (The model parameters may be estimated by conditional least squares or maximum likelihood methods.) Choosing a final model can be a complex process based on the weighing of a number of criteria. Most obviously, the estimated coefficients must be significant and within the necessary bounds. Further, the model residuals must not be different from white noise. This must be evaluated on the basis of an ACF, PACF, and Q statistic calculated from the model residuals (the Q statistic will have k-m degrees of freedom where m is the number of autoregressive and moving average parameters estimated in the model). Because the Q statistic can have low statistical power under certain circumstances, one should not rely on it exclusively in evaluating the autocorrelation of the model residuals (Granger and Newbold 1986, p. 100). In particular, the analyst should check that the values of the ACF are low at the first few regular and seasonal lags. These can be evaluated against the value of their standard errors computed from the sample ACF. Any values greater than or roughly equal to 2 times their standard errors should be considered carefully, even if the Q statistic is not significant.[3] [4]

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[3]A somewhat more conservative criterion in practice is to compare them against the value of $n^{-1/2}$ which is the asymptotic standard error of the autocorrelations of a white noise process (Granger and Newbold 1986, p. 99). Even this measure tends to overestimate the true standard errors of the autocorrelations, particularly when autoregressive or moving average components are in the estimated model. As Granger and Newbold (1986, p. 99) point out, models with autoregressive or moving average components result in parameter estimates whose values make the residuals of the ACF as close as possible to white noise, particularly for the first few lags. In other words, the estimation procedure for such models makes the first few lags of the ACF as close to zero as possible. Thus, even moderately large values at the first few lags of the ACF of a model

McCleary and Hay (1980, pp. 100-3) also recommend adding or subtracting components from a tentative model for comparative purposes. Two or more models which have acceptable parameter estimates and ACF's can be compared according to how well they fit the data. The residual standard errors of the models, for instance, can show whether one model fits the data substantially better than does another. Other goodness of fit statistics may also be utilized.[5] In comparing different models, an important principle is that of parsimony; in other words, the analyst should strive to develop a model that adequately captures the time series process with as few autoregressive and moving average parameters as possible. Thus, if two or more tentative models produce acceptable parameter estimates and ACF's, the analyst should favor the more parsimonious model, especially if the more parsimonious model provides a better or near equivalent fit to the data.

The ARIMA methodology provides a number of advantages relative to other time series methods. Empirical determination of the type of autocorrelation present in the data, for instance, can lead to better diagnosis and specification of autocorrelation (including seasonal variance), improve the reliability of parameter estimates, and reduce the chances of finding spurious relationships between variables

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with autoregressive or moving average components require close scrutiny.

[4]Pankratz (1991, p. 49) recommends special attention for low lag ACF coefficients which are 1.6 or more times their standard errors and seasonal coefficients which are 1.25 or more times their standard errors.

[5]Another commonly used goodness of fit measure is Akaike's (1974) AIC criterion. This is defined as $-2\ln(L) + 2k$ where ln is the logarithm of the likelihood function estimated from the model and k is the number of free parameters in the model. A lower value of the AIC statistic is indicative of a better fit.

(Granger and Newbold 1986, pp. 205-15; McCleary and Hay 1980, p. 271). To some extent, these advantages are dependent upon the use of relatively long time series. Experts tend to recommend that ARIMA methods be restricted to use with time series having 50 or more observations and certainly not many fewer than 40 observations (Granger and Newbold 1986, p. 81; McCleary and Hay, 1980, p. 20; Pankratz 1991, p. 26).

Other relevant points about the methods used in this project are contained in the text and footnotes of the main report.

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