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IT'S THE PHONE, STUPID: MOBILES AND MURDER

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It's the Phone, Stupid: Mobiles and Murder
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ABSTRACT

US homicide rates fell sharply in the early 1990s, a decade that also saw the mainstreaming of cell phones – a concurrence that may be more than a coincidence, we propose. Cell phones may have undercut turf-based street dealing, thus undermining drug-dealing profits of street gangs, entities known to engage in violent crime. Studying county-level data for the years 1970-2009 we find that the expansion of cellular phone service (as proxied by antenna-structure density) lowered homicide rates in the 1990s. Furthermore, effects were concentrated in urban counties; among Black or Hispanic males; and more gang/drug-associated homicides.

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1 Introduction

In the 1990s, US homicide rates fell sharply and have remained low since, remarkable considering the past decades' booms and busts; growing income inequality; rising gun sales; declining incarceration rates (since 2008, Kaeble and Cowhig [2018]), and burgeoning substance abuse (Desimone [2001], Case and Deaton [2015], Ruhm [2018], also Figure 1).

New York City provides a telling example. In 1990s, the city recorded 2,245 homicides. Ten years later, that number was down to 677, a 70% fall. New York City is but one data point, but it illustrates a wider trend of safer cities, safer big cities in particular. Take the country's three largest cities, New York City, Los Angeles, and Chicago. In 1990, they accounted for 5.6% of the US population but 20% of homicides, and had homicide rates exceeding not only the national average but also those of other cities. Ten years later, the country's three most populous cities looked like any other city, a remarkable convergence (Figure 2).

This paper investigates the role of cell phones[1] in this development. Mainstreaming of cell phones, we propose, changed how drugs were dealt. Instead of relying on a fixed location, trades could be coordinated in real time, undermining the need for open street markets. This development required cell phones to be cheap enough to be an everyday possession, something the transition from analogue to digital telephony in the 1990s helped usher in. By 2000, the number of subscribers stood at 100 million, up from a mere five million in 1990.[2]

Illicit drug use has a long history but started to seep into the US mainstream in the late 1960s with the youth-oriented hippie culture and the return of Vietnam war veterans. In large cities, open street markets emerged in which buyers and sellers could connect without prior arrangements. The need to physically spot each other while staying under the radar of law enforcement or "concerned citizens" limited the number of feasible venues. Buyers and sellers would coordinate on marginal, but publicly accessible locations such as poorly supervised street blocks or intersections. Control of that space – or "turf" – meant control of who could and who could not sell, thus allowing for cartelization of the retail market for drugs.

Cell phones removed the need for buyers and sellers to physically spot each other, thus reducing the importance of turf. Cell phones also provided a level of privacy unattainable in the street market. In the words of Murray [2001, page 51]: "[Cell phones] offered something completely new: Dialing a phone number now meant connecting with a *person* rather than a *place*."

The hypothesized link from cell phones to reduced violence runs via the demise of turf as a profit center for street gangs. Turf was local territory that could be patrolled and defended and thus allowed for drug retailing to be cartelized. The ensuing economic success of street gangs resulted in more violence because gangs tend to employe violence liberally in their everyday operations (to settle scores, fight off rivals, collect debts, impose

[1] More broadly, the role of two-way Commercial Mobile Radio Services, a class that also includes Specialized Mobile Radio (SMR) and Personal Communication Services (PCS). For brevity, when there is little risk of confusion, "cell phones" will be used to refer to this whole class.

[2] See for instance the Federal Communications Commission's *Annual Report and Analysis of Competitive Market Conditions With Respect to Commercial Mobile Services*, various years.

internal discipline, etc.). Furthermore, high gang profits may have generated violence around the fringes as aspiring or low-ranking gang members sought to establish their *bona fides* by acting tough [Johnson et al., 2000, Levitt and Venkatesh, 2000].

To obtain plausibly exogenous variation in cell phone uptake, we use a measure of network build out. Mobility in modern mobile telephony is achieved by calls being handled in a network of hexagonal cells. As the caller moves between cells, the call is handed from one cell to another. Each cell consists of an antenna structure (e.g., a tower), antennas, and a base station. To a first approximation, more antenna structures mean more cells and more cells mean better service. The Federal Communications Commission (FCC) maintains a public register of all antenna structures taller than 200 feet above ground. The register contains information on location and year of construction, allowing us to construct a local (county-level) measure of antenna density by year.

Our identifying assumption is that the build-out of the cellular network generated exogenous variation in mainstreaming of mobile telephony. We think this is a reasonable assumption for the 1990s when affordability and versatility of cell phones took major steps forward due to technological and regulatory advances. It was also a decade of rapid antenna-structure build-out (Figure 3). This assumption loses validity with distance to the 1990s. In short, the 1970s saw network construction but no service, the 1980s saw the introduction of cell phones, but the technology was analogue and low capacity and expensive, and the 2000s is a decade of saturation for basic voice and text services.

Our main finding is that annual, county-level mortality data for the contiguous US covering the four decades 1970-2009 lend support to our hypothesis that expansion of cellular phone service – as proxied by antenna-structure build-out – lowered homicide rates. Results vary with time and space in a fashion consistent with our hypothesis: they are strongest for the 1990s and among urban counties (those belonging to a Consolidated Statistical Area (CSA)). Our findings are robust to the inclusion of CSA-year fixed effects, as well as Donohue and Levitt [2019]'s state-year measure of abortion access,[3] and do not appear confounded by illicit drug use or economic activity as measured by county-level overdose and employment rates respectively. Compared to 1990, homicides in 2000 were down by about 10,000 and back-of-the-envelop calculations suggest that cell-phone mainstreaming can account for 1,900-2,900 of that decline.

We are not the first to propose that mainstreaming of mobile communication improved public safety, or to investigate the relationship empirically [Klick et al., 2002, Orrick and Piquero, 2015]. Using annual, state-level cell phone subscription data, Klick et al. [2002] found subscriptions to reduce rape and assault in the study period 1999-2007. Orrick and Piquero [2015] brought the analysis back to cover the 1990s, our decade of interest, but did so at the loss of sub-national granularity. Using national time series, they found support for cell phones having reduced property crimes but not violent crimes.[4]

We differ from Klick et al. [2002] and Orrick and Piquero [2015] empirically and conceptually. To start with differences in the empirical strategy, by exploiting network build out, we hope to sidestep some of the problems with usage measures. As pointed out by Klick et al. [2002], cell phones may be acquired prospectively to deter crimes or have higher use in areas that for reasons unrelated to cell phones see greater reductions in crime. Furthermore, we avoid the limitation that for most of the 1990s, subscription data only exist at the national level thus precluding a difference-in-difference analysis.

[3] We thank John Donohue and Steven Levitt for these data.

[4] Both studies used the Uniform Crime Reports for their crime statistics.

As for conceptual differences, they emphasized the deterrence effect of cell phones, whereas we emphasize the effect cell phones had on the business model of street-turned-drug gangs.

Evidence on gang related crimes seems germane to the question whether crime fell because of the improved ability to call a drug dealer as opposed to simply the ability to call the cops. The nature of gangs, however, makes such evidence scarce. Victims or witnesses are an important source of information on gang affiliation of perpetrators. For various reasons – fear of retaliation, feelings of loyalty, a desire to not get further involved, etc. – this information may not be shared with law enforcement. With these caveats in mind, we present evidence from three sources. First, the National Crime Victimization Survey (NCVS) is a nationally representative annual survey of the US population 12 years or older. While the NCVS does not cover homicides, it collects information on crimes whether reported to the police or not and for each incident asks (the victim) whether the offender was a gang member. Dividing crimes into violent and property crimes, we find gang involvement in violent crime not only dwarfed that in property crime, the 1990s drop in violent crime was accompanied by a drop in the *share* of violent crime with a gang connection. While not definitive, these pieces of evidence are supportive of a gang mediated mechanism.

Second, breaking down mortality statistics by race, age and sex, we find that antennas disproportionately reduced homicides among Black or Hispanic young men, a demographic group with higher gang membership than other race, age, gender demographic cell.[5]

Third, we use the Federal Bureau of Investigation (FBI) Supplementary Homicide Reports (SHR) which provide circumstance and victim-offender relationship information. Unlike the vital statistics, FBI data reporting is voluntary and the detail richness of the SHR is somewhat tempered by less than full coverage and a substantial fraction of cases being "undetermined." That said, using the SHR data we find antenna-structure build-out to have had a stronger impact on homicides more closely linked to gang and drug activities (e.g., juvenile gang killing) than on homicides with less of a link (e.g., hunting accident). As for the victim-offender relationship, the overall picture again is supportive, with homicides by strangers being among the types of homicides most affected by antenna-structure build-out. Furthermore, we find no effect for wife killings, consistent with gang members or drug dealers not being the marrying kind.

Many types of crime fell in the 1990s, not just homicide. We focus on homicide because it is a crime that is close to our hypothesis. It is also a well measured crime; the statistics are not susceptible to changes in victim propensity to report or arrest probability. While determination can be open to some slippage, once a death is considered a homicide, reporting is close to 100% [Bureau of Justice Statistics, 2014]. That said, homicide rates may correlate positively with other crimes and thus provide a window on them for two reasons. First, while homicide can be the intended end point, it can also be the deadly outcome of another crime [Maltz, 1999], say robbery or assault, in which case homicide may just be the tip of the proverbial iceberg. Second, we hypothesize that high homicide rates were driven by a weaponized gang environment, a factor that itself may give rise to crime.[6] A person carrying a gun for gang business may be tempted to also use it to rob or rape.

[5]For instance, National Gang Center. National Youth Gang Survey Analysis. Retrieved March 11, 2018, from `http://www.nationalgangcenter.gov/Survey-Analysis`.

[6]For evidence on the drugs-guns-homicide link, see Evans et al. [2018].

While almost a quarter century ago and time-bracketed, what brought down crime in the 1990s remains topical. First, our hypothesis suggests that low homicide rates may be the result of a regime shift, not just the outcome of a string of lucky breaks. Second, while the 1990s crime reduction need not be reproduceable (cell phones are not going anywhere), our findings suggest that the relationship between drug dealing and violence is complex and mediated by the market structure. Third, our paper relates to a small but growing literature on the equally growing substance abuse crisis where two phalanxes have crystalized, one viewing substance abuse through the prism of economic decline [Case and Deaton, 2015] and one that has drawn attention to the proliferation of prescription drugs [Ruhm, 2018]. We add low prices and ready availability of illicit drugs to the mix.

The remainder of the paper is structured as follows: We end this section with a brief discussion of the related crime literature. Section 2 provides a brief background on cellular telephony and the gang-drug-violence nexus. Section 3 describes the empirical strategy and Section 4 the data used. Section 5 presents results. Section 6 concludes.

1.1 Related Literature

Our inquiry falls on the heels of a large literature studying the 1990s' crime decline, for reviews see e.g., Levitt [2004], Roeder et al. [2015], O'Flaherty and Sethi [2015].[7] One strand of explanations has focused on reduced criminality of the cohorts coming of criminal age in the 1990s, highlighting factors such as lead abatement [Reyes, 2007, Aizer and Currie, 2017] or abortion liberalization [Donohue and Levitt, 2001, 2019].[8]

Other studies have emphasized contemporaneous factors such as economic opportunities; urban renewal [Diamond, 2016]; crack cocaine [Grogger and Willis, 2000]; policing policies, incarceration rates, or other facets of the criminal justice system [Kuziemko and Levitt, 2004, Chalfin and McCrary, 2017]. However, the 1990s and the 2000s through 2006 were economic boom years, followed by the Great Recession, and all the while economic inequality kept rising. Still crime fell and has remained low. Perhaps unsurprisingly, the evidence on the role of the economic environment has been inconclusive [Gould et al., 2002, Bushway et al., 2012]. As for the role of urban renewal, a level of interrelatedness is bound to exist if only because crime is a low-skill occupation. It is worth noting, however, that the ascendancy of centrality as a prized amenity has long been in the making. The trend was evident already in the 1980s [Edlund et al., 2016] but apparently did little to stop the crime wave of the late 1980s and early 1990s.

As the crack epidemic receded, so did the crime wave (Grogger and Willis [2000], also see Figure 1). However, explanations focusing on crack cocaine raise the question why drug use since has not resulted in similar or higher levels of violence. At least judging by overdose deaths, drug use has been steadily increasing since the 1980s, e.g., Jalal et al. [2018]. Certainly, overdose deaths have become more rural and more white, but that is a relative statement; in absolute terms, deaths have risen in urban areas as well.[9]

The second half of the 1990s saw a move away from open, visible-to-all, street transactions to indoor dealing. The change has been described as partly motivated by an interest

[7] For popular press coverage, see for instance, Neil Howe "What's Behind The Decline In Crime?" *Forbes* 28 May 2015; Dara Lind and German Lopez "Why did crime plummet in the US? *Vox* 19 January 2016 `https://www.vox.com/cards/crime-rate-drop`; Matt Ford "What Caused the Great Crime Decline in the U.S.?" *The Atlantic* 15 April 2016.

[8] For a critique, see Foote and Goetz [2008]).

[9] For the 1999-2015 period, see Mack KA [2017, table 2].

in protecting against robbery and partly as a response to more aggressive policing, and the role of mobile radio communication in this change has also been noted [Furst et al., 1999, Johnson et al., 2000]. Clearly, the link between cell phones and modes of drug dealing is not novel. Neither is the link between drug dealing and violent crime. However, to the best of our knowledge, we are the first to splice the two.

As noted in the introduction, our paper picks up a thread of the criminology literature focusing on the crime-reducing capability of technological advances, although the emphasis has tended to be on the edge technology lends law enforcement or law-abiding citizens. Other than cell phones, surveillance cameras, alarm systems, locks, etc. have all improved. Car locks are a case in point. Car theft used to be relatively low-skill, requiring little more than a blank key and a hammer. Starting in 1990, some high-end cars came equipped with mobilization technology requiring a computer chip embedded in the key fob to start the engine. However, uptake in the US was gradual and slow. By 2000, only about 10 percent of cars were thus outfitted [van Ours and Vollaard, 2016, figure 2], undermining the case for this technology to have played a major role in the decline in violent crime.[10] Technological advances also underpinned the "broken-windows" policies popularized by the New York City Police Department.[11] Lastly, the reduced amount of cash in circulation has affected the gains from robbery accordingly.[12]

Lastly, our paper is also related to Bertoloai and Scorzafave [2018] who proposed that the use of cell phones among Brazilian inmates reduced homicides. Their hypothesized mechanism, however, is quite different from ours. Cell phones, they argued, allowed one gang to gain hegemony within the prison system by facilitating coordinated, in-prison attacks on rival gang members; this in-prison hegemony could then be leveraged to drug-dealing hegemony throughout the state since dealers caught were likely to end up in a gang controlled prison.

2 Background

This section motivates why we think cell phones reduced violence in the US and why in the 1990s. To that end we will briefly discuss drug dealing and the use of violence in illegal organizations, but we start with a short history of mobile telephony.

2.1 Mobile telephony

The crime fighting potential of mobile radio communication was recognized early, with police departments being among the early adopters in the 1920s. Come World War II and two-way communication found extensive military use. Modern wireless communication relies on calls being transferred in a network of hexagonal cells. The concept was worked out in the 1960s and the first prototype call was placed in 1973. Commercial service, however, had to wait another ten years. In 1983 the infrastructure was in place to offer the service commercially in Chicago and the Baltimore-DC area (where it had operated an experimental basis since 1977). Other major cities followed in 1984. Initially, coverage

[10] For instance by restricting the availability of getaway cars. The share of homicides directly attributed to motor vehicle theft is exceedingly small, see Table A2.

[11] Specifically, the computer program CompStat `https://en.wikipedia.org/wiki/CompStat`

[12] As for drug-sales linked robberies, payment by cryptocurrency reduces the risk further. However, these currencies appear, by and large, outside of our study period. Bitcoin was launched in 2009.

was limited to the subscribers "home" city; truly national coverage would be another 15 years. Through the 1980s, the handsets were expensive, mono-functional, and barely portable (often designed to work in cars, so called "car phones").[13] Even the "pocket phone," introduced in 1986, weighed 15 ounces and $3,295 [Murray, 2001, page 214].

To accommodate this new service, the FCC made additional spectrum available. Each market was given two licenses, one which was given to the existing wireline operator (one of the Regional Bell Operating Companies or RBOCs) and the other one to a non-wireline provider.[14] While the non-RBOC operator constituted competition, they were fractionalized and often could not even offer regional coverage. The result was a sleepy duopoly of Baby Bells and local providers [Murray, 2001], perhaps fitting for an analogue network that could only handle a handful of phone calls at a time. In sum, in the 1980s, cellular telephony was far from a mass market service.

This situation was to radically change in the 1990s, principally because of the transition from analogue to digital telephony (2G) launched in 1991.[15] The 1990s is replete with milestones, from the first SMS to the 100-million subscriber mark. However, the first half of the 1990s stands out. In particular, a number of events shaping market structure make 1993 notable.

First, the 1993 Omnibus Budget Reconciliation Act made additional spectrum available for Personal Communications Services (PCS), a wireless technology that was digital from the start and provides a service very similar to cellular telephony (the first auction opened in December 1994).

Second, in 1993, AT&T entered the wireless phone business with the purchase of McCaw Cellular Communications (the merger was completed in 1994). The entry of AT&T brought nationwide coverage one step closer. The way in which spectrum had been allocated (by lottery for a decade) and a "free market" approach to the industry meant that the US market was highly fractionalized (compared to Western Europe), with phones, switches, even billing, being unable to handle calls across operators, and operators were often local. Seamless, cheap, nationwide calling was an obvious goal that could popularize wireless telephony. In 1998, AT&T introduced the first flat-rate plan with national coverage, the Digital One Rate plan. It was an instant success.

Third, 1993 is when a third, hitherto overlooked, system went on-line in LA. Using dispatch spectrum bought on the cheap and equipment developed by Motorola, Nextel (formerly Fleet Call) offered a radio that also worked as a phone, and *vice versa*.

Meanwhile, handsets and service plans became more consumer friendly. To start with the phones themselves, they saw improved functionality and battery life, all while shedding bulk and weight. For instance, in 1994, Motorola introduced the MicroTAC, which retailed for around $600 ($970 in 2016 CPI adjusted dollars), substantially lower than the $4,000 price tag of the initial phones (in 1983 or $9,000 in 2016 dollars). In 1995, the Nokia GSM phone, yet cheaper, lighter, and more versatile, reached the American market.

[13] Wikipedia: "The Motorola DynaTAC 8000x commercial portable cellular phone received approval from the FCC on September 21, 1983. It was priced at $3,995 in 1984, its commercial release year, equivalent to $9,209 in 2016 dollars."

[14] To handle the volume of applicants, the existing application process was scrapped for allocation by lottery, the first of which was held in the spring of 1984.

[15] Simply put, a phone call between points A and B can be likened to highway traffic between them. Analogue technology is the equivalent of an entire lane being dedicated to a call, limiting call capacity to the number of lanes. Digital telephony, on the other hand, is more like regular use of a highway, each car occupying only a fraction of lane space.

As for service plans, in the early 1990s phone plans varied in a myriad of ways: the charge for incoming and/or outgoing calls; the first minutes of a call; the time of the day and the day of the week; in-network or roaming, etc, complicating price comparisons. By the mid-1990s, competitive and technological forces combined to give budget conscious consumers more options. Pre-paid cards were introduced in 1994, eliminating the need for a long-term contract (or to provide identification, pass a credit check, etc.). For those not minding the lock-in of a contract, bare-bones "road-side assistance" plans could be had for $15/month, while users springing for more minutes could get plans that included a basic phone [Federal Communications Commission, 1997].

In 1994, the retail price per minute started to drop after years of little sign of change [Hazlett, 1999, figure 2]. In terms of contract expenditures, the average local monthly bill dropped from $95 in 1988 to $52 in 1995, a level it would maintain through the 2000s (CTIA).[16]

In 1998 cellular telephony was common enough to be included in the CPI [Hausman, 1999], and around the turn of the century the subscription base crossed the 100-million mark, or roughly one subscription per household.[17]

Expansion continued apace in the 2000s, in no small part driven by the introduction of smart phones. In 2000, the first camera phone appeared. In 2003, the BlackBerry 7230 introduced full web browsing. The iPhone arrived in 2007. The decade also saw the appearance of the term "burner phone" (circa 2002) illustrating both the usefulness of mobile phones for illegal activities as well as the near disposability of what was once a luxury item. Table 1 provides a brief summary of these events.

Our hypothesis is about cheap mobile two-way communication (or Commercial Mobile Radio Services (CMRS)), whether by Specialized Mobile Radio (SMR) and Personal Communication Services (PCS), or cellular telephony. This CMRS category also includes pagers but pagers may have been less consequential for our hypothesis because they did not provide two-way communication (until cell phones and CMRS siblings did so and on the cheap). Nevertheless a note on pagers is warranted.

Pagers made a brief but noteworthy foray into the mainstream in the 1980s. Pagers were largely limited to one-way, highly abbreviated communication and their popularity in the 1980s speaks volumes about the then state of cell phones. (Pagers existed before 1980 but their range had been too limited to provide more than mobile intercom within a work site or similar.) In 1980 wide-area pagers with city, even national range were introduced. Additional functionality included ability to display a number and, by the mid 1980s, a brief message.

By the end of the 1980s, the role of pagers in drug distribution was clear to the point of service providers taking counter measures.[18] Unlike the cell phones of their time, they were affordable enough to make their way into high schools where they conferred a certain status on their carriers.[19] However, pagers appear to have mainly impacted communication

[16] `http://files.ctia.org/pdf/CTIA_Survey_MY_2012_Graphics-_final.pdf`

[17] The Wireless Association `https://www.ctia.org`

[18] Jim Schachter. "Paging Service Hopes Surcharge Gives Drug Dealers the Message" LA Times October 06, 1988,
`http://articles.latimes.com/1988-10-06/business/fi-4446_1_paging-service`
Moses, Jonathan M. "Message Is Out On Beepers" Washington Post July 11, 1988,
`https://www.washingtonpost.com/archive/politics/1988/07/11/message-is-out-on-beepers/58840caa-523e-413b-9224-60ad94d7803f`

[19] Sims, Calvin. "Schools Responding to Beeper, Tool of Today's Drug Dealer, by Banning It" New York Times September 25, 1988.

between dealers and suppliers.[20] Why that was can be speculated about. Perhaps the one-way and highly limited amount of information that could be communicated kept pagers from affecting street dealing.

2.2 Illegal Drug Dealing

Illegal drugs, like any other product, reach the end user via a multi-legged journey. Our hypothesis concerns the last leg and in particular the market Johnson [2003] labelled "public networks" (as opposed to "private networks"' and "freelance public distribution"). Wrote Johnson [2003, page 4]: "Public networks involve sellers and lower-level distributors making sales to buyers in public settings (streets, parks) and even in private spaces (bars, clubs, stores, hallways and common areas of buildings). Buyers/sellers rarely know each other personally." Why shifting drug retailing away from the public network market would reduce violence is a germane question, clearly, drug use has not declined. The role of gangs is our proposed answer, shifting the question to why drug gangs are violent.

2.2.1 Gangs-Drugs-Violence?

Street or youth gangs had been part of the urban landscape well before the crime waves of the 1980s and 1990s, organizing working-class male youth often along lines of ethnicity or nationality. Activities ranged from socializing to petty crime and occasional street fights with rival gangs. As narcotics use become more common in the 1970s, gangs started to control street dealing. The money making potential in drug dealing quickly outshone those of other activities [Howell and Decker, 1999]. Cue the drug gang, a more moneyed and more violent version of the street gang. Gang membership has since been strongly associated with homicides (e.g., Decker and Curry [2002]), as well as a slate of other crimes (e.g., National Gang Intelligence Center [2013]).

Wrote Johnson et al. [2000, page 180] about the late 1980s:

> So many people were striving to make "crazy money" that competition among sellers was the major problem. ... The more-organized crack sellers introduced a variety of violent innovations to control competition and increase their profits. Crew leaders started to hire a "protector" to defend turf and enforce sanctions against operatives. Many of these muscle men were perceived as "crazy," or unpredictably violent, which enhanced their image, instilled fear in others, and increased their worth. ... [juveniles] quickly learned of enhanced job opportunities associated with acting crazy. ... One of the most effective tactics towards this end was to talk about, display, or use guns.'

But why are drug gangs violent to start with? Illegality and profitability emerge as key factors, dimensions we now turn to.

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https://www.nytimes.com/1988/09/25/us/schools-responding-to-beeper-tool-of-today-s-drug-dealer-by-banning-it.html

[20] Tibbets, Wendy. "Technology: What was it like when people used beepers and not cell phones?" July 5, 2017.
https://www.quora.com/Technology-What-was-it-like-when-people-used-beepers-and-not-cell-phones

To start with illegality, the cost-benefit calculation for illegal organizations favors violence. Its dual, legality, offers a number of benefits, including protection against confiscation of property and access to judicial recourse. Use of violence is one way to lose legal status, a margin of relevance for the legal enterprise only.[21] Thus the cost of violence is higher for legal than illegal outfits.

As for the benefits, violence is one way to enforce property rights and settle conflicts particularly attractive to illegal organizations. While legal organizations tend to favor contractual obligations and third party enforcement, notably by courts, this avenue is fraught with difficulties for the illegal organization. Courts are loath to enforce contracts on illegal activities. Furthermore, courts lean heavily on written contracts, documents the illegal organization tends to avoid since they also constitute prime incriminating evidence [Reuter, 1985].

Thus, the cost-benefit calculation for violence looks better for illegal than legal organizations. Still, not all illegal organizations use violence pointing to additional considerations, a matter of interest to us since we argue that homicides fell because of changes to the retailing of illicit drugs.[22]

Profits, territoriality, and ambiguity are additional factors. Since the State has an obvious interest in curbing lethal violence and also has considerable resources at its disposal, organizations will only resort to lethal violence if the profits from so doing are high.[23] Drug selling, especially if cartelized, can provide such profits.

Territory dependent profits, the case in turf-based drug dealing, fans violence because territory is physical space that can be attacked or defended.

Lastly, a level of ambiguity is required. If an outcome is certain, then the parties can economize on the fighting. Periods of uncertainty, for instance because of a weak(ened) incumbent (e.g., Dell [2015]), may trigger violence. In terms of market entry, the in-between case may be more conducive to violence than the extremes: secure monopoly (e.g., Bertoloai and Scorzafave [2018]) or free entry (the case considered here).

In sum, drug dealing in the US in the 1980s and early 1990s exhibited above four features conducive to lethal violence: illegality, profitability, territoriality and ambiguity. This situation may have come to an end with the mainstreaming of cell phones. The cell phone allows buyers and sellers to make contact and improvise on the point of exchange, rendering redundant the fixed market place. In the 1990s, in particular in the later half, cell phones became affordable enough to be everyday possessions. In 1997, a New York Times article noted that drug dealing had moved indoors.[24]

If cellular telephony freed sellers from the need for turf access, then the lower barriers to entry should have resulted in lower drug prices. In fact, prices fell. In 1990, a gram of heroin cost about $300 (inflation adjusted to 2015 dollars). Today it can be had for a third of that,[25] and, interestingly, the price decline was steepest in the 1994-2001 period.[26]

[21] Non-State combatants pose a direct threat to the State and it is therefore unsurprising that private armies, militias, even duelling [Tilly, 1990] are highly circumscribed in modern states.

[22] For anectdotal evidence, see e.g., Miroff, Nick "Mexican traffickers making New York a hub for lucrative – and deadly – fentanyl." *Washington Post* 13 November 2017.

[23] In addition to attracting the attention of law enforcement, violence creates bad-will in the affected communities, deters customers, and demoralizes the rank and file [Levitt and Venkatesh, 2000].

[24] Rohde, David. "Where Has Your Neighborhood Drug Dealer Gone?" *The New York Times* 17 August 1997.

[25] *Washington Post*, August 27, 2015: "Why a bag of heroin costs less than a pack of cigarettes."

[26] United Nations, reported in "Heroin Prices" *The Economist* 25 June 2009.

Lower prices suggest squeezed profit margins, reduced gang income and with it the appeal of gangs. While gang activity is difficult to measure, it appears that after a prolonged period of steady increase [Miller, 2001], youth gang membership declined through the later half of the 1990s and held steady between 2000 and 2012 (latest year available).[27] Furthermore, youth gangs may have assumed a less crime-oriented identity, for instance, by being more inclusive and less cohesive than in the past [Pyrooz and Sweeten, 2015, Morselli et al., 2017].

Data from the National Crime Victimization Survey (NCVS) also suggest reduced gang activity. The NCVS is a nationally representative annual survey that has existed in its current form since 1992.[28] The NCVS seeks to capture victim accounts of crimes. A strength of the NCVS is that it reports crimes regardless of weather reported to the police. Furthermore, it asks victims whether the offender was a street gang member. Drawbacks include: (i) the sample framework means that it does not cover persons currently homeless or in correctional facilities, two groups with high victimization rates; (ii) it is a sample and nationally representative statistics are obtained using weights; and (iii) the focus on first-person victimization accounts means that homicides are not covered. Still, the NCVS can shed light on gang prevalence, types of crimes gangs engage in, as well as changes over time. To start with, the NCVS show a drop in violent and property crime victimization similar to that observed in FBI data (although the decline appears somewhat later, see Figure 4). Turning to types of crime, the NCVS confirms the stereotype of gangs as violent. Gang involvement in violent crime stood at almost 10% in the mid-1990s, dwarfing that of property crimes (0.25%=25/10,000). Furthermore, the decline in violent crimes in the second half of the 1990s was accompanied by a halving of the share of crimes with gang involvement (Figure 5), consistent with gangs being important originators of violent crimes.

3 Empirical Strategy

Turning to our regression analysis, we estimate a model of the following form:

$$HOMI_{ct} = ANT_{ct} + \alpha_c + \alpha_t + \epsilon_{ct}, \tag{1}$$

where:
$HOMI_{ct}$ – Homicides per 100,000 inhabitants in county c and year t.
ANT_{ct} – Antenna structure density in county c and year t.
α_c, α_t – county and year fixed effects.

In our preferred specification, regressions are population weighted and standard errors are clustered at the county level. Year fixed effects control for time effects common across counties. County fixed effects control for time-invariant county characteristics, such as pre-existing infrastructure or demographic profile. Specifications will also introduce location-specific time trends.

This approach explores *within* county variation in antenna-structure density under the assumption that the *timing* of the build-out is unrelated to other determinants of

[27] National Youth Gang Survey Analysis `https://www.nationalgangcenter.gov/survey-analysis/measuring-the-extent-of-gang-problems`

[28] Data on crime victimization has been collected by the Census Bureau since 1973, initially by the National Crime Survey. The NCVS started to be phased in the late 1980s, early 1990s. Concatenated NCVS files exists for the years 1992-2015.

homicides. However, cell network expansion was not random. For instance, population density clearly played a role, metropolitan areas were covered before rural ones. It is also quite conceivable that areas with more economic activity, or slated for such, saw greater infrastructure investments. Conversely, better infrastructure could attract new firms and change the employment prospects of the local population, or the local population itself, with attendant consequences for crime (e.g., Dix-Carneiro et al. [Forthcoming]). There could also be an affect on crime through drugs being cheaper and easier to obtain.

Here, the 1970s may prove useful since there was no cell phone service, cell construction in that decade was in preparation of service. Assuming that the relationship between antenna structure placement and economic activity was the same in the 1970s as the other decades, the 1970s could serve as "placebo." No effect on homicides in this period would support the case for antenna-structure build-out being unrelated to other determinants of violence.

Another tack is to examine the exogeneity of antenna-structure placement to county indicators of economic activity. We will focus on rates of county OD deaths and employment. Under our hypothesis, more antennas should have made drugs cheaper and easier to obtain and to the extent that higher drug use (as opposed to profits in drug dealing) leads to homicides, this effect would go against us. The employment rate proxies for the economic environment. If antennas were put in place in economically more successful areas, this could introduce a spurious negative association between antennas and homicides.

4 Data

We draw on two main sources, the FCC's register of antenna structures[29] and Vital Statistics mortality files. We supplement the mortality data with FBI's Supplementary Homicide Reports. We aggregate the individual-level data to the county level.

We restrict the study to the contiguous United States and the years 1970-2009 (data are missing for 1989). These four decades cover the rise and decline in crime as well as many signature dates in the development of cellular telephony. The end year falls before the emergence of the "Silk Road," and other darknet sites, as well as the proliferation of synthetic opioids.

Our analysis sample has some 120 thousand county-year observations. There were 3,118 counties or county equivalents in the contiguous US (in 2016). For the 1990s, our focal decade, we capture 3,100 or more of these counties, missing counties being rural and small (population wise).

4.1 Homicide

The United States uses two national data collection systems to record homicides: the Federal Bureau of Investigations's Supplementary Homicide Reports (SHR) and the National Vital Statistics System (NVSS) [Bureau of Justice Statistics, 2014].[30]

The NVSS data are maintained by the National Center for Health Statistics (NCHS) and draw on death certificates. The NCHS data contain information on the date and cause

[29] `http://wireless.fcc.gov/uls/index.htm?job=transaction&page=weekly`

[30] National Center for Health Statistics. Mortality Data File for 1990-2014 with all county identifiers, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program.

of death.[31] Reporting is mandatory but the homicide classification can be a judgement call (e.g., absent witnesses or clear evidence) [Bureau of Justice Statistics, 2014].[32]

The public-use files include county (occurrence or residence) identifiers for all counties prior to 1990. For the years 1990 and onwards, we use the restricted-use data with county identifiers for all counties.[33] We use the county of occurrence and limit the sample to US residents.

Additional contextual information can be had from the Supplementary Homicide Reports (SHR), part of the FBI's Uniform Crime Reporting (UCR) Program. The SHR provide information on the apparent circumstances and the victim-offender relationship.[34] The data are at the incident level and reported by individual policy agencies on a monthly basis. As detailed by Maltz [1999], this additional granularity comes at a cost. Agency participation is voluntary and police departments vary in the priority given to filing. Many agencies fail to report for all or some months of the year. Among those that report, diligence varies. Further, while the circumstances surrounding a homicide can be legitimately unknowable, the "undetermined" category is large and probably contains "determinable" cases.

4.2 Illicit Drug Use

The NCHS mortality data also offers a measure of illicit drug use, overdose (OD) deaths. Overdose deaths are coded as death by "poisoning by medical or biological substances, whether intentional, accidental or homicide." We follow Ruhm [2016, table 1]'s coding of ICD-10 cause-of-death codes.[35]

As a snapshot of contemporaneous drug use, mortality data have some obvious drawbacks. First, while habitual consumption of illicit drugs trends fatal, use may be ongoing for many years making overdose deaths a lagging indicator. Second, inconsistent potency of a drug tends to raise fatality rates as illustrated by the deadliness of synthetic opioids such as fentanyl and carfentanyl. Third, not all overdose deaths are caused by illicitly obtained drugs, viz. legally obtained prescription drugs [Ruhm, 2018]. Fourth, the OD classification may depend on the results of a toxicology test and there is no national standard for when such is to be performed, thus reporting varies by time and jurisdiction [Seth et al., 2018]. Still, overdose deaths may be the best nationwide county-year measure of illicit drug use available for the study period.

4.3 Antenna Structure Density

A cellular network is made up of cells, each consisting of a base station and antennas mounted on a structure, for instance a tower or a mast. If the antenna structure rises

[31] We omit year 1989 because for this year, only a subset of counties are reported.

[32] The number of homicides reported by the NCHS is higher than that reported by the FBI. The main difference is that the FBI, being interested in crime, excludes justifiable homicides (e.g., by law enforcement or by civilians in self defense).

[33] After 1990, only counties with more than 100,000 population are identified in the public-use files.

[34] The SHR captures death by the location of the offence.

[35] That is, All Drug Poisoning Deaths, ICD-10: X40-44, X60-64, X85, Y10-14. We do not include, Y35.2 (legal intervention), or *U01.6, *U01.7 (terrorism). The ICD-10 code has been used since 1999. For earlier years, cause of death was recorded using ICD-8 (1970-1978) and ICD-9 (1979-1998), and we code cause of death in these earlier years to align with the ICD-10 coding.

more than 200ft above ground or is within sight of an airport, it needs to be registered with the FCC.

The FCC register contains information on location (coordinates) and year of construction. It also gives height above ground, which allows us to filter out low antenna structures (otherwise, areas close to airports would appear more antenna-structure dense without that necessarily being the case). To calculate density (structures per 1,000 square miles of county land area), we match the antenna structures to counties using Census information on county centroids.[36]

The antenna structures were assigned as follows. First, each structure was assigned to the closest county (centroid) as well as any county within 20 miles. Then, the number of structures assigned to a county was summed, where structures assigned to multiple counties were partially counted (an antenna structure assigned to n counties was counted as $1/n$ in each county). Considering the finite capacity of antenna structures (and antennas), we think this is a reasonable assignment.

To obtain a density measure, we divide the number of antenna structures by the county land area.

For time variation in antenna structure density, we use the year of construction. That is, once constructed, we assume that the structure stays there. While this may not be literally true, the study period was one of expansion.

For ease of exposition, we will occasionally let "antennas" substitute for "antenna-structure density."

While we proxy cell-phone uptake by density of registered antenna structures, three (at least) caveats are worth bearing in mind. First, antennas have a number of uses (tv, radio, public safety radio communication). We do not know which one(s) an antenna structure was used for. Still, by 1973, the above were mature technologies with high level of penetration and therefore to a first approximation, expansion since 1973 largely reflects the growth of CMRSs.

Second, the relationship between structures and service has not been constant. Initially, towers were built and operated by individual phone companies. The 2000s see the emergence of independent tower companies that lease out antenna space, allowing one tower to serve several networks.

Third, the FCC registry covers only towers rising 200ft or more above ground (or within sight of an airport). Over time, the cells making up the cellular network have become smaller, thus lowering the height demands of antenna structures. This development accelerated in the 2010s (outside our study period).

4.4 Combined Statistical Areas – CSAs

Our hypothesis primarily concerns urban violence, turf requiring some population density. Therefore, we are interested in grouping counties by a measure of urbanicity. In addition, we are interested in grouping counties belonging to the same metropolitan area to control for common economic shocks. To these ends, we use the Combined Statistical Area typology, the Census states: "Combined statistical areas (CSA) consist of two or more adjacent metropolitan and micropolitan statistical areas that have substantial employment interchange."

[36] County centroid and land area information as of year 2000, `http://www.census.gov/tiger/tms/gazetteer/county2k.txt`.

Using the year 2013 classification, there were 166 CSAs in the contiguous United States. The New York-Newark CSA (population 23 million) was the largest CSA, followed by Los Angeles-Long Beach and Chicago-Naperville. The smallest CSA was Steamboat Springs-Craig, CO (population 37,757, 2016 estimate).

CSAs counties are more urban than non-CSA counties and account for about 75% of the population (in the contiguous USA).

On average, there were about seven counties per CSA. To further zero in on urbanicity, we designate the county containing the main Central Business District (CBD) of the CSA as "main." Many CSAs contain multiple cities or towns, and we give the main designation to the CBD county of the first named locality. For instance, for the New York-Newark CSA, New York City is named first and Manhattan contains the CBD, thus Manhattan is the main county. In a handful of cases, the CBD abutted two or more counties, in which case they were all given the main designation.[37]

5 Analysis

We start the analysis with some descriptives. Figures 6-9 show the decadal change in antenna density by county. Table 2 details these changes by county urbanicity. Clearly, the 1990s is the decade with the most expansion. Overall, mean antenna density increased from 14.6 to 22.9 antennas (per 1,000 square miles). The increase was higher in urban areas. Among CSA counties, antenna density increased from 17.3 to 26.7, whereas among the main CSA counties the increase was from 20.1 to 30.2.

The 1990s also saw homicide rates (per 100,000 population) almost halve, dropping from 11 in 1990 to 6.2 in 2000. Broken down by urbanicity, the respective numbers for CSA counties were 11.9 and 6.5, a decline of 5.4 homicides (per 100,000 population). For main CSA counties, homicides rates fell from 17.3 to 9.5 between 1990 and 2000, a reduction of almost eight homicides (per 100,000 population).

Our hypothesis turns on a change in the relationship between drug dealing and violence. Figure 10 reports the correlation between homicides and overdose deaths (conditional on county fixed effects) by year for the period 1970-2009. We see that from the mid-1970s to the mid-1990s, the correlation was positive and rose with the overdose death rates, consistent with the homicide waves around 1980 and 1990 (Figure 1) being drug related. Before that period, OD rates were low and so was the correlation with homicides, again supportive of homicide rates being drug related. After the mid-1990s, however, the relationship breaks down. OD deaths are high and rising but the correlation with homicides falls and fails to be statistically significance, consistent with our hypothesized change to the relationship between drug dealing and violence.

We now turn to the regression analysis.

5.1 Regression Results

Table 3 shows the results from estimating variations of Equation 1 on the full sample (counties in the contiguous US, years 1970-2009, except 1989). Simply regressing homicide on antennas yields a positive relationship, contrary to our hypothesis (Column 1). The

[37] For the list of CSA names, see `https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/bulletins/2017/b-17-01.pdf`.

positive association is strengthened by the inclusion of year fixed effects (Column 2) but turns negative when county fixed effects are included (Column 3). The addition of county-decade fixed effects strengthens the negative relationship (Column 4) and the estimated effect maintains significance once the standard errors are clustered at the county level (Column 5).

We next present results from alternative ways of computing antenna density and the results remain similar. Column 6 shows the results from simply summing antennas assigned to a county. This raises the antenna density substantially and likely more so for urban counties. This measure performs equally well as the "share" measure used in Columns 1-5.

Column 7 dispenses with the height restriction and include all registered antennas irrespective of height above ground. Since antenna structures rising less than 200ft above ground only need to be registered if close to an airport, removing the height restriction raises antenna density in counties with airports. As expected, this cruder way of computing antenna density results in a less precise coefficient estimate.

As mentioned, we expect the relationship between antennas and homicides to vary by decade. In the 1970s towers were constructed but there was no cellular service. In the 1980s, the service existed, but it was expensive and phones were bulky and mono-functional. It is not until the 1990s that we expect cell phones to have a meaningful impact on drug retailing.

Table 4 uses our preferred specification (i.e., Column 5, Table 3) to look at subsamples by decade and by county type. To start with the decadal breakdown. Consistent with our expectation, the coefficient in the 1970s is highly insignificant (Column 1). The coefficient is negative in the 1980s and is borderline significant. Fast forward to the 2000s, the estimated coefficient is close to zero. By contrast, for the 1990s, the estimated coefficient is negative and statistically significant at the 5 percent level.

We expect the effect to be stronger in more densely populated areas and restricting the sample to CSA counties, this is also what we find. The estimated effect is larger and is estimated with greater precision in the main CSA counties (Column 5) compared to all CSA counties (Column 6). In rural (non-CSA) counties, the estimated effect is not significant (Column 7).

5.2 CSA counties, 1990s

As hypothesized, results were stronger in more urban counties and in the 1990s. Henceforth, we will limit the analysis to CSA counties and the 1990s.

Table 5, Panel A, Columns 1 and 2 restrict the sample to the main CSA counties. Results remain negative and significant. Adding CSA-specific quadratic time trends (Column 2) substantially reduces the coefficient estimate (but raises precision). The attenuation is perhaps not surprising considering that for this subset, in most cases, there is only one county per CSA.

In Columns 3-5, we expand the sample to all CSA counties allowing us to include CSA-specific year fixed effects. Interestingly, inclusion of CSA-specific time controls (quadratic time trend or year fixed effects) does not reduce the point estimate which is about 70% of that estimated for main CSA counties (Column 1). Antenna structure density in CSA counties went from 17.3 to 26.7, an increase of 9.4. An estimated coefficient of -0.154 thus implies a drop of 1.45 homicides per 100,000 population in CSA counties comparing year

2000 to year 1990 (see Table 2), or 27%(=1.45/5.43) of the observed decline in these counties. Translated into homicides per year, this represents a reduction of 2,900(=1.45×2,000) homicides.[38]

Confounders It is possible that our results are confounded by factors that correlated with antenna-structure density. Infrastructure expansion targets economically more promising areas, or conversely, beefed up infrastructure boosts economic activity. The economic environment, in turn, could plausibly impact homicide rates. Therefore, we substitute the county employment rate for homicide as the dependent variable (Table 5, Panel B). We expect antennas to be positively correlated with economic activity and thus employment levels, which in turn could reduce homicide rates (e.g., Dix-Carneiro et al. [Forthcoming]) and thus form a potential confounder. However, contrary to our expectations, results indicate a negative and insignificant association (with the exception of the specification in Column 2).

Another possible confounder is that antenna structures and cell-phone mainstreaming plausibly made illicit drugs cheaper and easier to obtain, factors that could plausibly increase drug use. Greater drug use in turn could raise homicide rates, for instance from psychopharmacological effects or erosion of social networks.

Results from making the county overdose rate the dependent variable are shown in Table 5, Panel C. The only statistically significant result obtains in the main CSA county sample and the specification including CSA-specific time trends (Panel C, Column 2), and the estimated effect is positive. Under the assumption that drug use corrodes interpersonal relations this result would work against finding a negative effect of antennas on homicides.

In sum, potential confounders go against us or fail to reach statistical significance.

Abortion Our proposed explanation follows on the heels of a number of factors proposed to have brought down crime in the 1990s. The role of abortion access [Donohue and Levitt, 2001, Foote and Goetz, 2008, Donohue and Levitt, 2019] is of particular interest, not least because unlike mobile radio communication, legalized abortion in the US continues to face legal challenges.

Our results control for CSA-year fixed effects, which capture most state-year variation present in the Donohue and Levitt abortion-access measure. However, CSAs and state are not entirely collinear (41 of the 166 CSAs straddled two states or more). Therefore, we start by adding state-year fixed effects. We see that the coefficient on Antenna remains significant but is attenuated by 10-20% (Appendix Table A1, Panel A). While reassuring, we next swap out the state-year fixed effects for the Donohue and Levitt abortion measure.[39] The coefficient on the abortion measure is significant (in four of the five specifications) and of the expected sign, but more importantly for our interests, the estimated effects of Antennas remain significant and are quite close to those obtained in specifications without the abortion control, suggesting that cell phones and abortion may constitute two independent explanations.

[38] CSA counties had about 200 million population in 1995. For the contiguous US vital statistics show 27,218 homicides for 1990 and 17,321 homicides for 2000, a drop of 9,897. (These numbers are higher than those reported by the FBI because *inter alia* FBI statistics exclude justifiable homicides, e.g., self defense or defense of others).

[39] From Donohue and Levitt [2019].

Race and Age So far we have ignored demographics, but gang violence tends to prey on its own. The National Youth Gang Survey (1996-2011) estimated that 40-50% of gang members to be juveniles (under 18); more than 90% male, and about 80% Black or Latino/Hispanic.[40] Therefore, we now turn to male homicides and two race groups: Black/Hispanic and non-Hispanic White.[41]

For reasons of sample size, we focus on five-year age bins between ages 15 and 39. We restrict the sample to county-year observations with more than 100 males in the relevant age and race cell.[42]

Figure 11 presents the coefficients and 95% confidence intervals from estimating the equivalent of Table 5, Column 5 specification on race-by-age sub-samples. We see that the estimated coefficients are consistently negative for Blacks/Hispanics whereas for Whites, the estimated effects are close to zero and only statistically significant for the 15-19 age group.

5.2.1 Homicide Context

Our hypothesis suggests that types of homicides more closely related to drugs or gangs would be more affected by cell-phone mainstreaming. To that end, we turn to the FBI's Supplementary Homicide Reports which report on homicide circumstance and victim-offender relationship.

In addition to drug dealing, crimes found to have high street-gang involvement include assault, robbery, and threats/intimidation (see Figure 5, also National Gang Intelligence Center [2013, page 14]). Therefore homicides with such mentions are of particular interest to us. As for victim-offender relationship, we expect killings by strangers to be more affected than, for instance, employer-employee killings or spousal murder (gang members not being the marrying type).

Before going into the results, a note on coverage is warranted. Unlike Vital Statistics data, SHR reporting is voluntary. Notable absences for part or whole of the 1990s are DC, Florida, and Louisiana, homes of "high crime" cities such as DC, Miami and New Orleans. Missing counties and partial reporting from counties means that for our sample covering the 1990s and CSA counties, the SHR covers about half of the homicides reported in the Vital Statistics.

Partial reporting raises the question what population figure to use for calculating rates. The SHR provides reporting agency population figures, but unfortunately this information is zero or missing in a non-trivial number of cases. Therefore, in the preliminary analysis, we considered three approaches: (i) the county population; (ii) the county aggregate of agency (ORI) populations where missing values were treated as zeros; and (iii) only included counties for which no agency (ORI) reported missing population values.

[40] National Gang Center. National Youth Gang Survey Analysis. Retrieved March 11, 2018, from `http://www.nationalgangcenter.gov/Survey-Analysis`.

[41] Hispanic status was not reported on the death certificate by Oklahoma (1990-1996), Louisiana (1990) and New Hampshire (1990-1992) for indicated and therefore records for those states and years are excluded. Additionally, decedents whose Hispanic status was stated as unknown were included among the Black or Hispanic group and excluded from the non-Hispanic White group.

[42] We experimented with 100, 200, and 500 cutoffs and found the results to be quite similar, but with drastic effects on sample size. So as to minimize sample selection due to a high cutoff, we choose 100 as our cutoff level. A population of 100 means that if a homicide were to occur, the implied rate per 100,000 population is 1000.

While the three approaches resulted in different population counts and analysis samples, results were very similar across the three approaches. Therefore, we chose (i), the county population, as it produces the more straightforward sample: counties with at least one agency reporting to the SHR. These "SHR-reporting" counties form the universe for our analysis of the SHR information on homicide by context (Tables 6-8).

Circumstances Figure 12 shows the series of homicides (counts) grouped into five broad categories: Narcotics-Gang, Argument, Theft, Miscellaneous and Undetermined (a list of the specified circumstances are in Appendix Table A2). These five groups move with remarkably synchronicity in the 1990s, but arguably the first three are more closely related to drugs and gangs. Narcotics-Gang groups circumstances explicitly mentioning drugs or gangs. Arguments is the single most common category and while somewhat generic, gang culture may be one reason an argument turns deadly, gang culture being characterized by a weaponized environment in which toughness is feted [Johnson et al., 2000, Levitt and Venkatesh, 2000, Johnson, 2003] allowing minor incidents to escalate [Sethi and O'Flaherty, 2010]. Theft is the third category of interest, it covers robbery, theft and larceny. As noted, gangs are crime generalists, drug sellers can make for attractive robbery targets, and theft is one way for addicts to finance their addiction. These three groups accounted for almost half of the homicides covered by the SHR.

Remaining homicides can be split into two roughly equal sized groups: Miscellaneous and Undetermined. The circumstances grouped under Miscellaneous had a less clear link to drugs or gangs, examples include "brawl due to influence of alcohol," "lovers triangle," "victim shot in hunting accident."

Since the SHR does not cover all counties, we start by replicating the results of Table 5, Panel A for the SHR-reporting counties using the NCHS homicide data. We see that results also hold in this sub-sample. Although effect sizes are smaller, coefficient signs go in the same direction and reach statistical significance, confirming previous findings.

Turning to homicide circumstance, estimates are of the expected sign and mainly statistically significant for the three groups of homicides arguably most closely linked to gangs and drugs: Narcotics-Gang, Argument, Theft (Panels B-D). Further, the estimated effect size is the largest for Narcotics-Gang group.

By contrast, antennas appear to have no effect on homicides in the Miscellaneous group (Panel E), consistent with our hypothesis.

Panel F considers homicides without a specified circumstance, either because the SHR reported the circumstance as Undetermined or because the homicide was not covered by the SHR. In other words, the outcome variable in Panel F is the number of homicides reported in Panel A minus the homicides reported in Panels B through E. We find no effect, one interpretation of which is that the SHR information on drug and gang related homicides does capture the bulk of such homicides.

Victim-Offender Relationship The early 1990s brought the term super-predators – juvenile gang members with the ruthlessness and moral compass of child soldiers, wrote Dilulio: "They live by the meanest code of the meanest streets, a code that reinforces rather than restrains their violent, hair-trigger mentality. In prison or out, the things that super-predators get by their criminal behavior – sex, drugs, money – are their own immediate rewards. Nothing else matters to them."[43]

[43]Dilulio, John. "The coming of the super-predators" The Weekly Standard, November 27, 1995.

The conjured picture of youth capable of indiscriminate violence suggests that gang violence may be particularly related to killings by strangers. To investigate this possibility, we turn to the victim-offender relationship information contained in the SHR. Four broad categories emerge: Strangers (17%), Friends and Acquaintances (32%), Family (15%), and Undetermined (66%) (for a list of specified relationships, see Appendix Table A3). We expect the link to drugs and gangs to be in descending order, Strangers, Friends and Acquaintances, and Family. Figure 13a shows the time series and again the synchronicity in the 1990s is striking.

Table 7 present regression results, again focusing on the 1990s and the CSA counties. The effects for homicide by Strangers was arguably the strongest, the estimates are significant at conventional levels once controlling for CSA-level time varying effects (Panel A, Columns 2, 4 and 5). The coefficient estimate in Column 5 suggests that an increase by 10 antennas/1000 square miles reduced murders by strangers by 22 per 10 million population, a 15%(=22/150) reduction of this type of homicide.

The estimated effect on homicides in the Friends and Acquaintances group is weaker; the level of statistical significance is lower, as is effect size (Panel B). The implied effect of an additional 10 antennas/1000 square miles is around 10%(=29/274).

For Family, estimates are more precise, but the effect size is yet smaller (Panel C). Column 4 suggests that a 10 antenna/1000 square miles increase in antenna-structure density resulted in 0.7 fewer homicides (per 10 million population), or a 5%(=7/135) reduction. The largest individual relationship category is Undetermined and we find no effect (Panel D).

That Strangers would be the group with the most important effect lines up with our expectations. We were, however, surprised to find effects for Family – gang warfare being quite distinct from domestic strife. Therefore, we divide the Family category into the following groups: spouses, partners, natal family (parents, siblings, offspring) and others (see Figure 13b).

Before going into the result, it may be useful to consider the profile of a typical low-level drug dealer, wrote Johnson [2003]: "Almost no low-level distributors and few sellers pay for their own apartments/home or support a family. In the United States, many lower-level distributors live at severe poverty levels. This is true even when their sales income appears to be substantial," life circumstances perhaps more memorably summarized by "Why do drug dealers live with their moms?"[44] In sum, the typical drug dealer appears to be an unmarried man who has yet to establish an independent household.

Table 8 presents the results, where the first four panels show the results for spouses and partners, and the last two panels group family according to whether natal (parents, siblings, offspring) or not (in-laws, exes, step-children, step-parents, or other family).

The largest individual victim category is Wife, and here we find no effect – the point estimate is small and the standard errors are large. In addition to being consistent with the typical drug dealer not being married, this finding is interesting because, as has been noted (e.g., Levitt [2004]), most crime, not just homicides or violent crimes, fell in the 1990s, and looking within homicides, most types of homicides followed the pattern of high rates in the beginning of the 1990s and a sharp drop about 1/3rd into the decade. The pattern for wife (and husband) victims also follow this pattern in the 1990s. Yet, we find no effect of antenna-structure density on spousal homicides, consistent with spousal homicides being driven by other factors, e.g., Stevenson and Wolfers [2006]. By contrast,

[44] Freakonomics, chapter 3 title.

the girlfriend category has seen a steady increase in numbers but we find antennas to have had a tempering effect. (The effects for Boyfriend are weaker and fail to reach statistical significance at conventional levels.)

As for non-partner family, we find effects for natal family members (Panel E), but not other family (Panel F).

Taken together, these results (Table 8) paint a picture of reduced everyday violence by young, unmarried men living at home (possibly from reduced presence of guns around the home, c.f. Evans et al. [2018]). Investigation of victim ages corroborates this picture. The sons and daughters killed were young, the modal victim was an infant (not reported). A possible mechanism is that reduced profitability within gangs has lowered the status and return to lethal violence, thereby reducing the presence of handguns in and around the homes of gang members/drug dealers.

6 Discussion

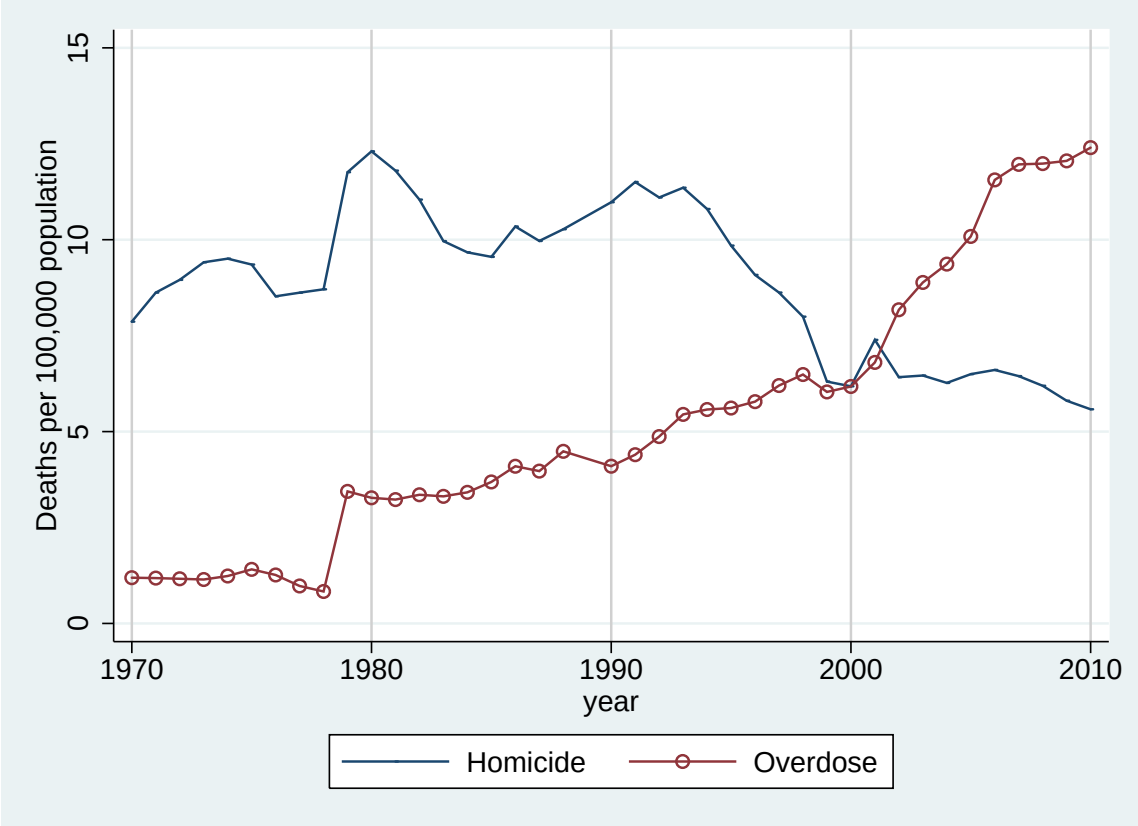
This paper has provided evidence that cell-phone mainstreaming contributed to the drastic reduction in homicide rates seen in the 1990s and maintained since. Our argument is straightforward. Cell phones removed the rationale for illegal drugs to be sold at a fixed location. As a result, drug retailing was de-cartelized, eroding the economic base for street-turned-drug gangs, entities known for their ready employ of violence. We proxy cell-phone uptake by the build-out of cellular phone networks and find that antenna-structure density reduced homicides in the 1990s, the decade cell phones went from niche to mainstream. Consistent with cell phones bringing down gang-related violence, we found effects to be confined to urban areas (counties within a Combined Statistical Area), street-dealing being a distinctly urban phenomenon. Furthermore, drilling down on types of homicides we found stronger effects for Black or Hispanic male victims and categories of homicides more closely associated with gang violence and drug dealing. By contrast, we found no effect on spousal homicides, a non-finding consistent with low marriage rates among rank-and-file gang members.

Compared to 1990, homicides in 2000 were down by about 10,000 and back-of-the-envelop calculations suggest cell-phone mainstreaming can account for 1,900-2,900 of that decline, leaving plenty of room for additional factors. The fact that homicide rates today vary substantially across localities further underlines the partial nature of our findings. For instance, in 2017, the homicide rate in Baltimore was 55.8 per 100,000 population, or 16 times higher than that of New York City, a difference hardly attributable to differences in cell-phone penetration.

The decline (and preceding rise) in violent crime has been a US phenomenon. Our findings point to the circumstances of how illicit drugs are retailed, factors likely to be more salient in the US, arguably the number one consumer market for narcotics (e.g., Peacock et al. [2018]).

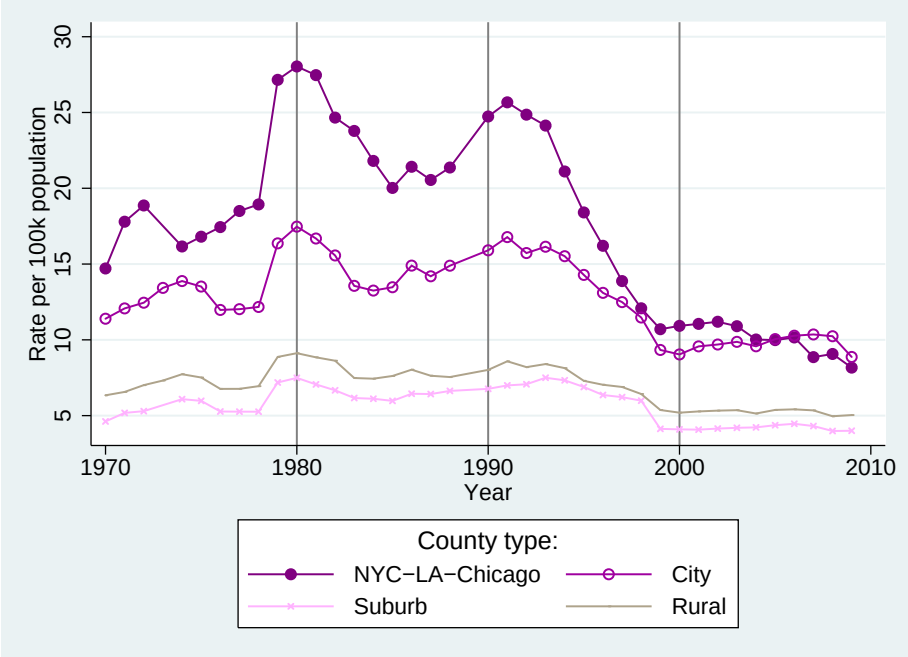
Our findings suggest that cell phones removed a cash cow for US street gangs, increased public safety and reduced prices, many of the advantages touted by advocates of legalization of drugs. Cell phones may also have contributed to an increase in drug use, a scenario feared by opponents of legalization. Thus, we may already have been offered a preview of some of the pros and cons of drug legalization.

Figure 1: Homicide and Overdose Death Rates



Source: NCHS. Notes: Contiguous USA. Data are missing for 1989.
We use vital statistics data which show higher number of homicides than FBI statistics. This is because of different procedures and definitions. By law, a death certificate needs to be filed National Vital Statistics System for each death. In case of homicides this is noted as the cause of death on the death certificate by the medical examiner or coroner. By contrast, the FBI is interested in crime. An investigation may reveal that the killing was justified (e.g., done by law enforcement or civilians in self defense) and these deaths are not part of the FBI statistics.
The jump in OD deaths in 1979 may be associated with the change from ICD-8 to ICD-9 coding. Homicide deaths are less likely to be affected by this change.

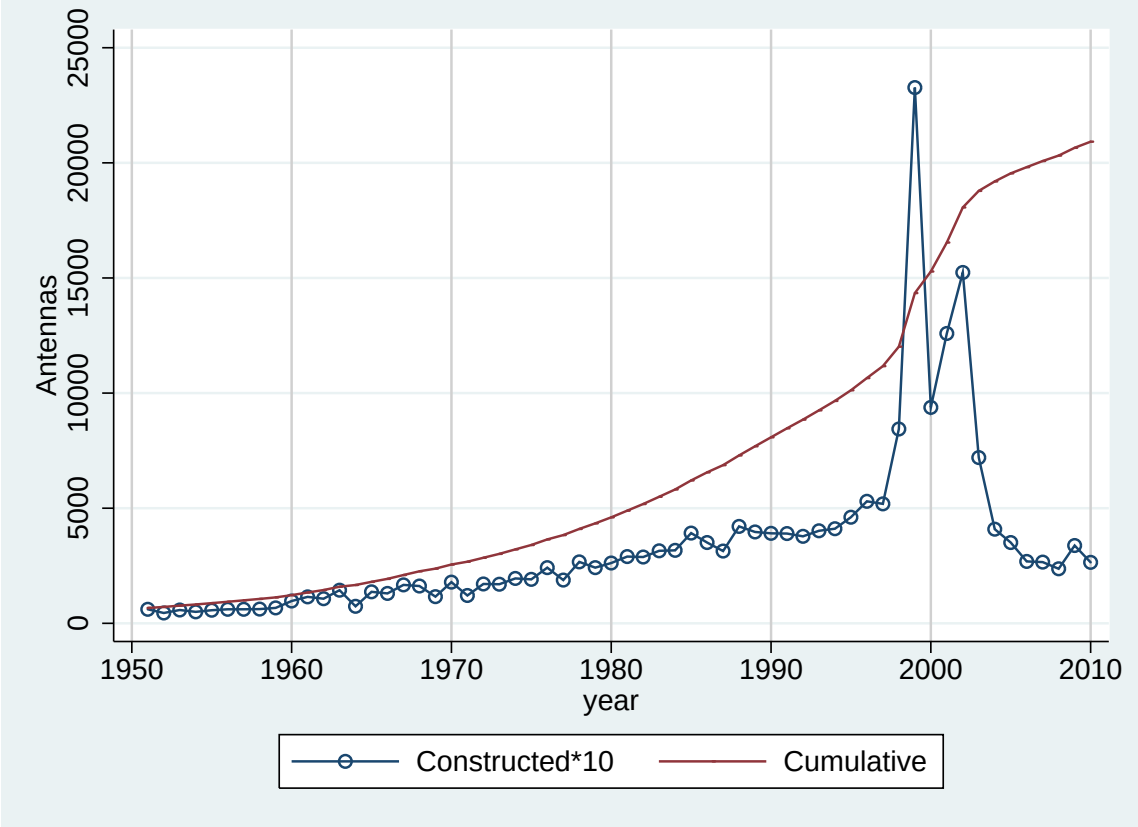
Figure 2: Homicides by County Type – Rate per 100,000 population



Source: NCHS. Notes: Contiguous USA. Data are missing for 1989.

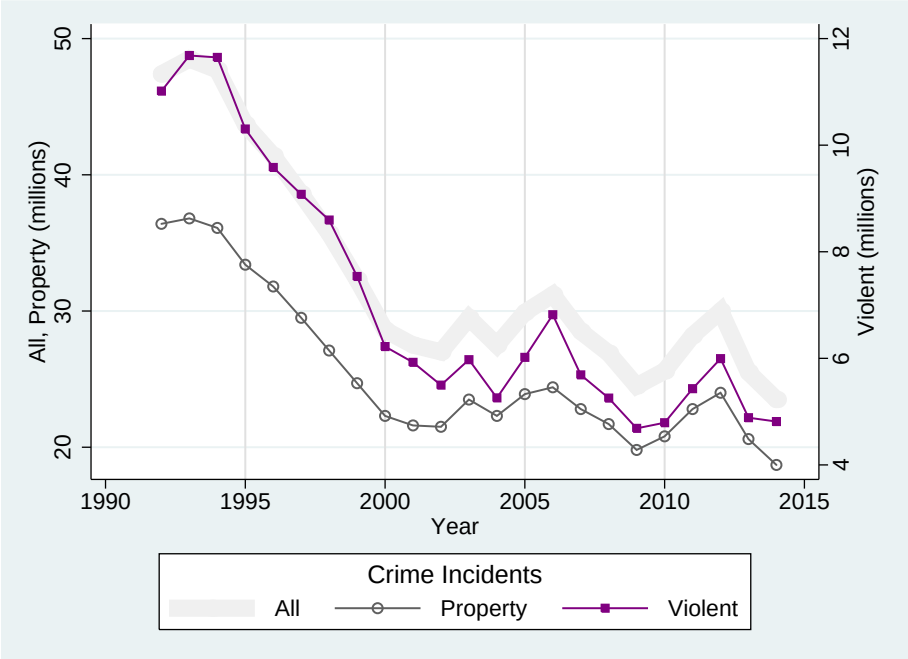
Notes: NYC-LA-Chicago includes the counties of New York City, Los Angeles, and Chicago (the five NYC boroughs, LA county and Cook county);
City includes main CSA counties (except NYC-LA-Chicago as defined above);
Suburb includes remaining CSA counties (neither NYC-LA-Chicago nor City);
Rural includes all non-CSA counties (in contiguous US).

Figure 3: Antenna Structures (200ft above ground)



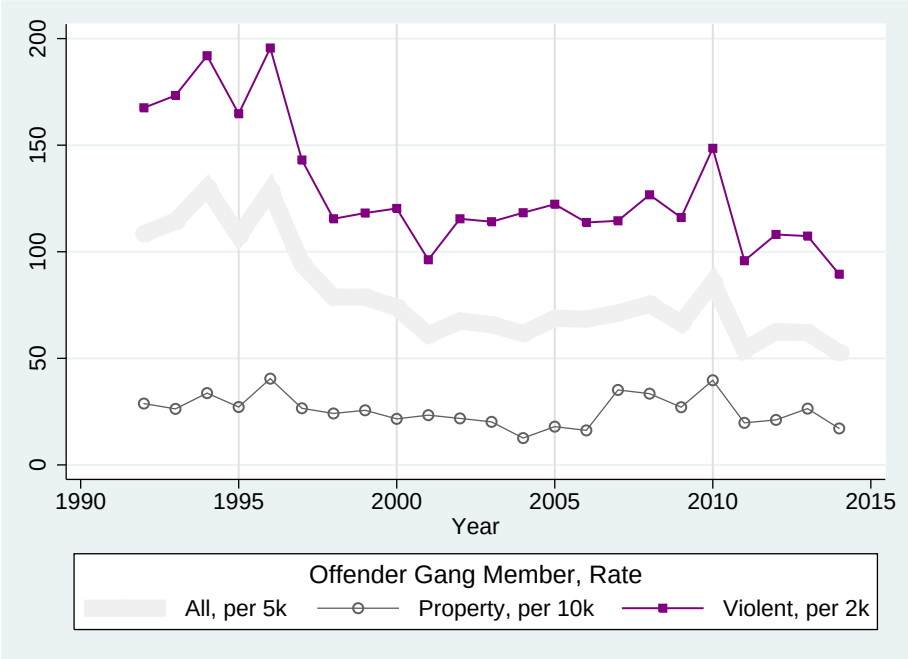
Source: Federal Communications Commission.
Notes: Contiguous USA.

Figure 4: Estimated Crime Incidents



Source: National Crime Victimization Survey, Concatenated File, 1992-2015.
`https://www.icpsr.umich.edu/icpsrweb/NACJD/studies/36456`
Notes: All crimes are divided into Property and Violent crimes.
Property crimes group (attempted and completed) purse snatching, pocket picking, personal larceny, burglary, household larceny and motor vehicle theft.
Violent crimes group (attempted, completed or threatened) rape, assault, and robbery.
Grouping purse snatching and pocket picking with violent crimes does not affect results.

Figure 5: Rate of Gang Involvement



Source: National Crime Victimization Survey, Concatenated File, 1992-2015.
`https://www.icpsr.umich.edu/icpsrweb/NACJD/studies/36456`
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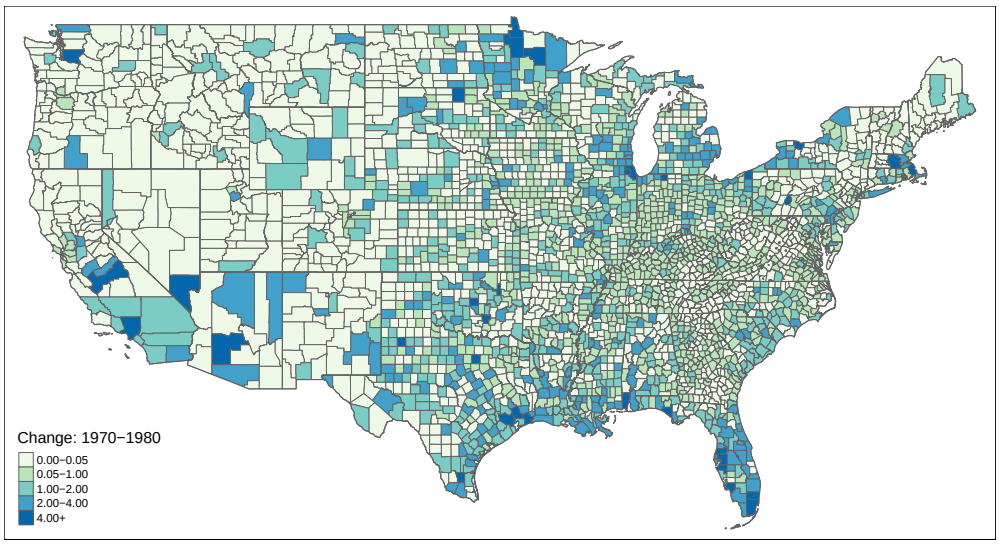
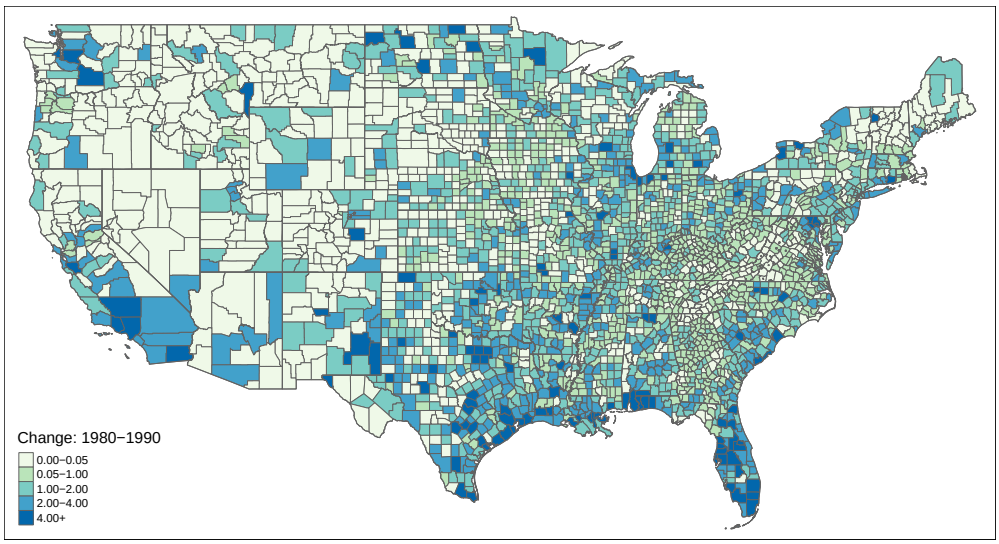
Grouping purse snatching and pocket picking with violent crimes does not affect results.

Figure 6: Antenna structures (200ft+)/1000 square miles – Change 1970s



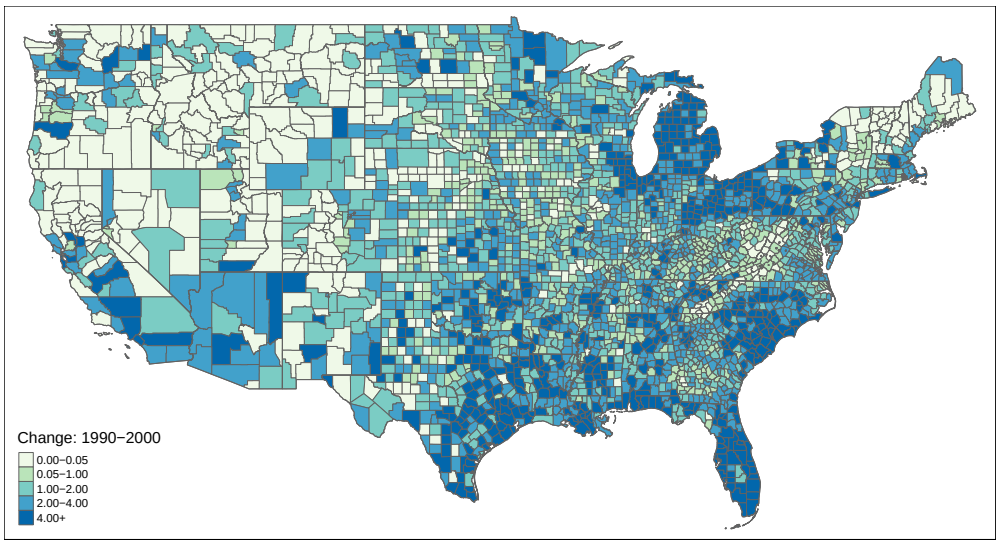
Source: Federal Communications Commission.

Figure 7: Antenna structures (200ft+)/1000 square miles – Change 1980s



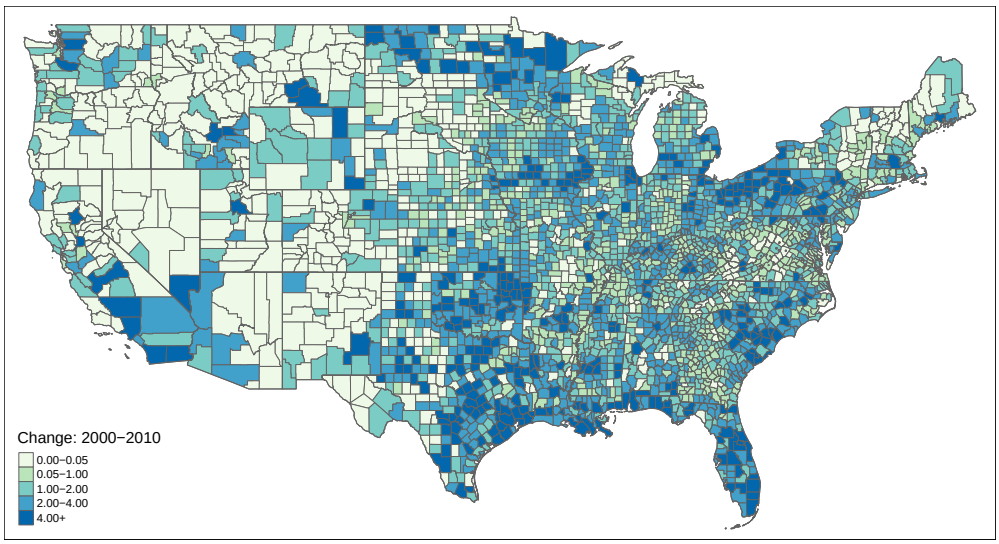
Source: Federal Communications Commission.

Figure 8: Antenna structures (200ft+)/1000 square miles – Change 1990s



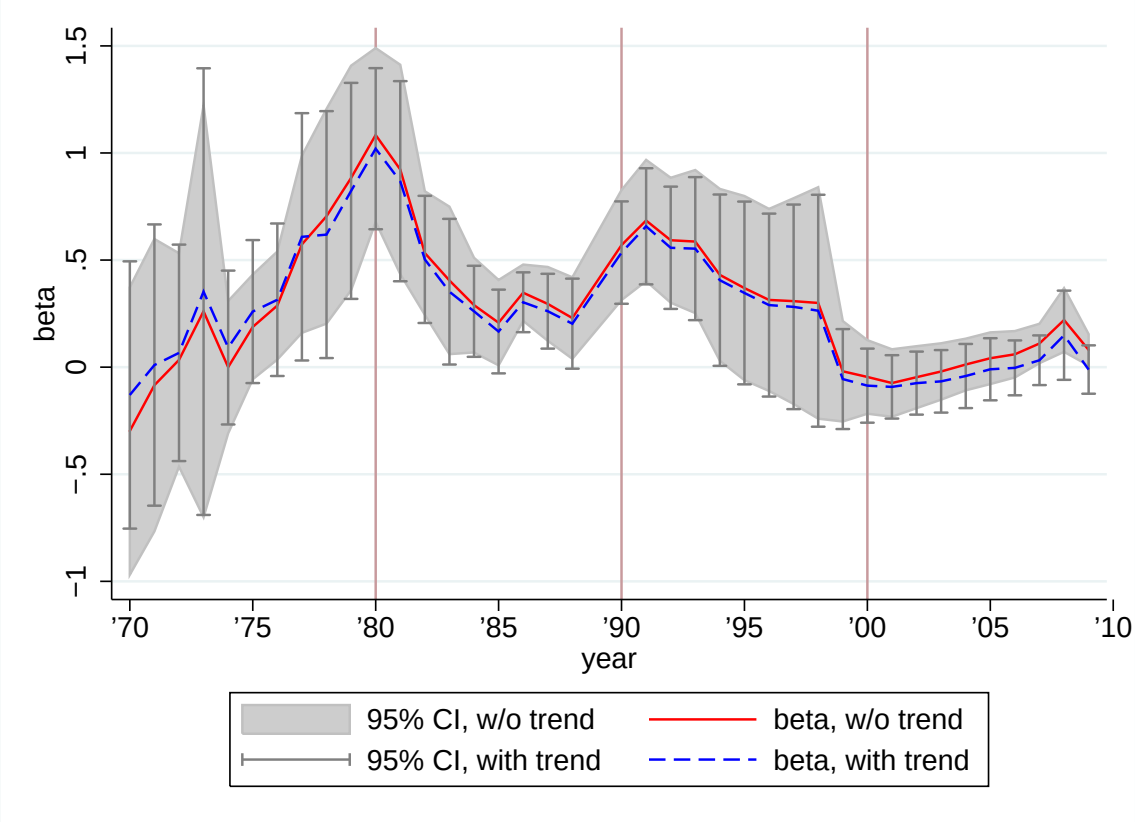
Source: Federal Communications Commission.

Figure 9: Antenna structures (200ft+)/1000 square miles – Change 2000s



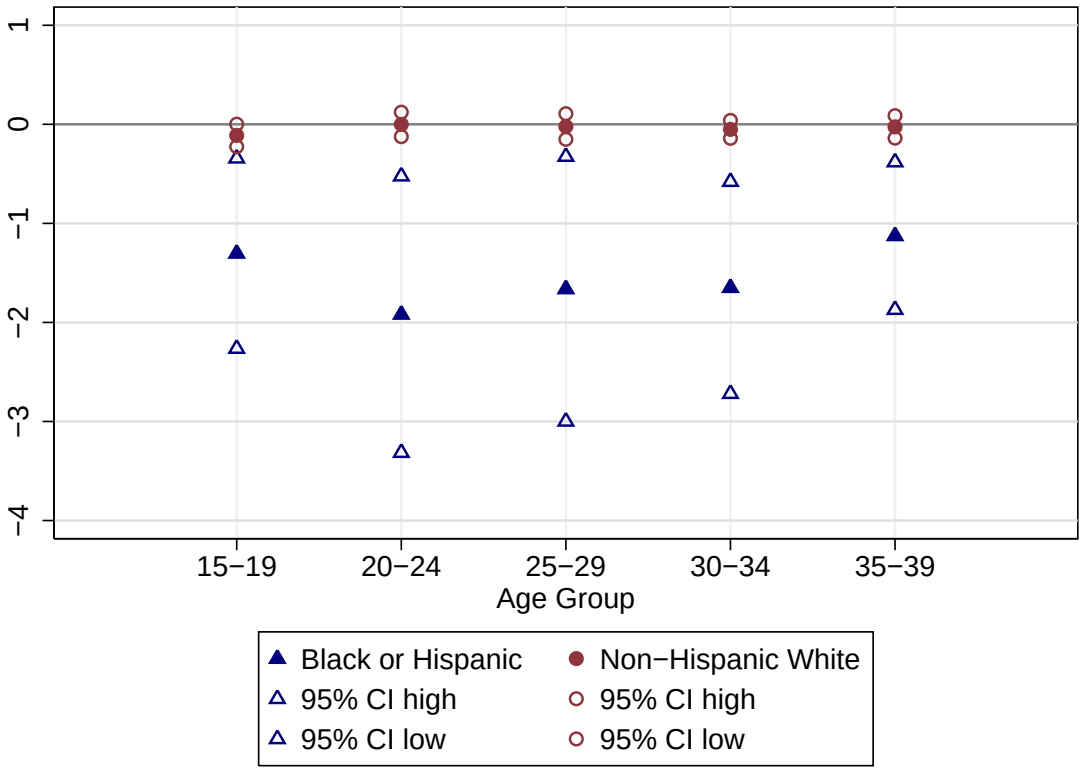
Source: Federal Communications Commission.

Figure 10: Homicide and Overdose Correlation



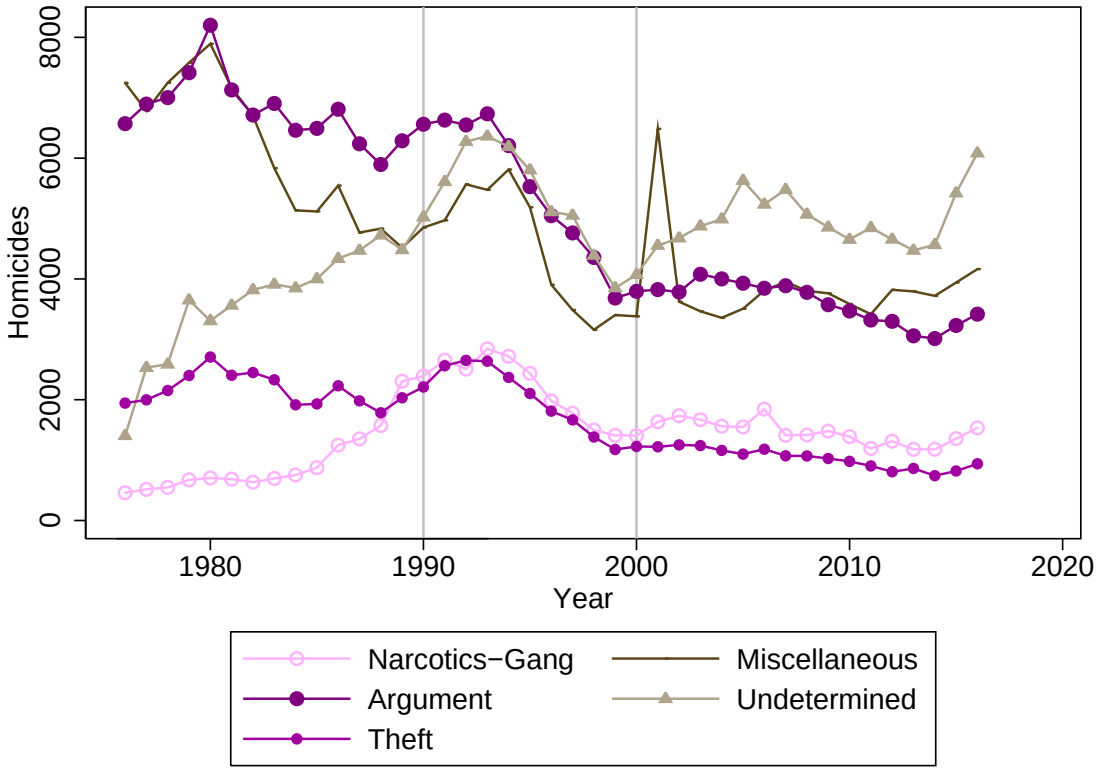
Source: NCHS.
Notes: The figure plots regression coefficients and 95% confidence intervals from regressing county homicide rates on overdose rates, year- and county fixed effects, with and without CSA-specific quadratic trends respectively. The sample is restricted to CSA counties in the contiguous USA. Data are missing for 1989.

Figure 11: Effects of Antenna Density on Male Homicide Rates: by Race and Age

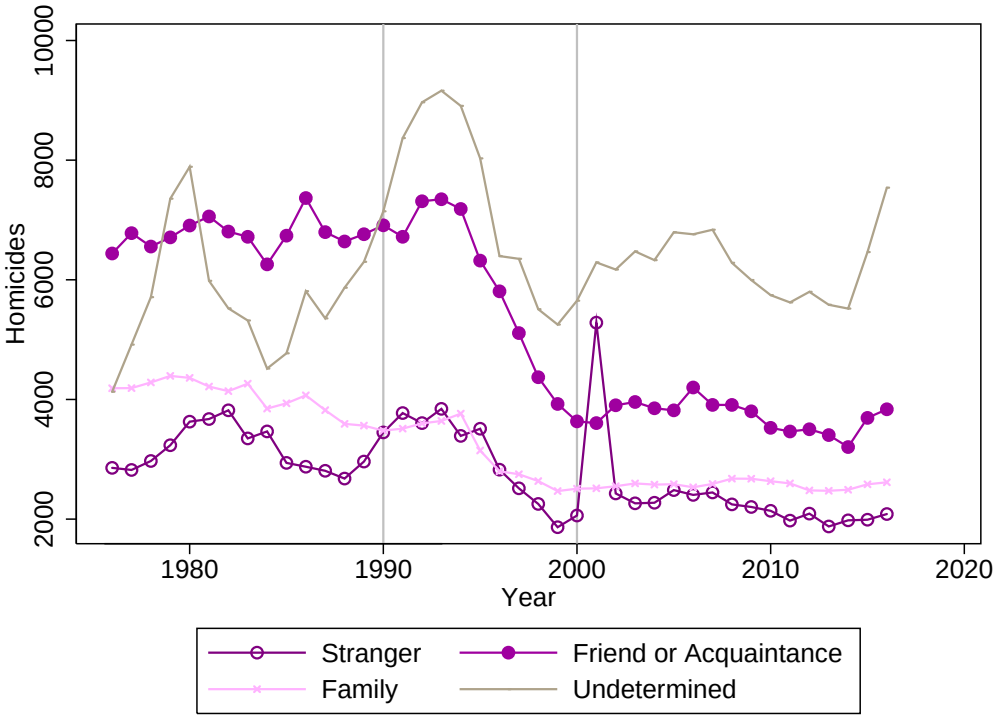


The graph shows the coefficients from the Table 5, Column 5 specification, estimated for the indicated race and age groups. That is, the sample is restricted to the years 1990-1999 and to CSA counties, and the regressions include CSA-specific year fixed effects, county fixed effects and standard errors are clustered at the county level.
The antenna measure is density per 1,000 square mile land mass and the homicide measure is homicides per 100,000 population.
Counties with fewer than 100 men in the relevant age and race/ethnicity group were excluded. The reduction in sample size was greater for Black and/or Hispanic, a group for which the number of county years is reduced from around 11,250 to around 7,250 (varies slightly with age group). For non-hispanic whites, the sample reduction was about 170 county-year observations.
The reason the full sample does not have 11,490 county-years (cf. Table 5) is that following states did not report Hispanic status on the death certificate and are therefore were dropped for the years in parentheses: Louisiana (1990), New Hampshire (1990-1992), Oklahoma (1990-1996).
Black and/or Hispanic includes "hispanic origin unknown."
Non-Hispanic White excludes "hispanic origin unknown."
Source: NCHS.

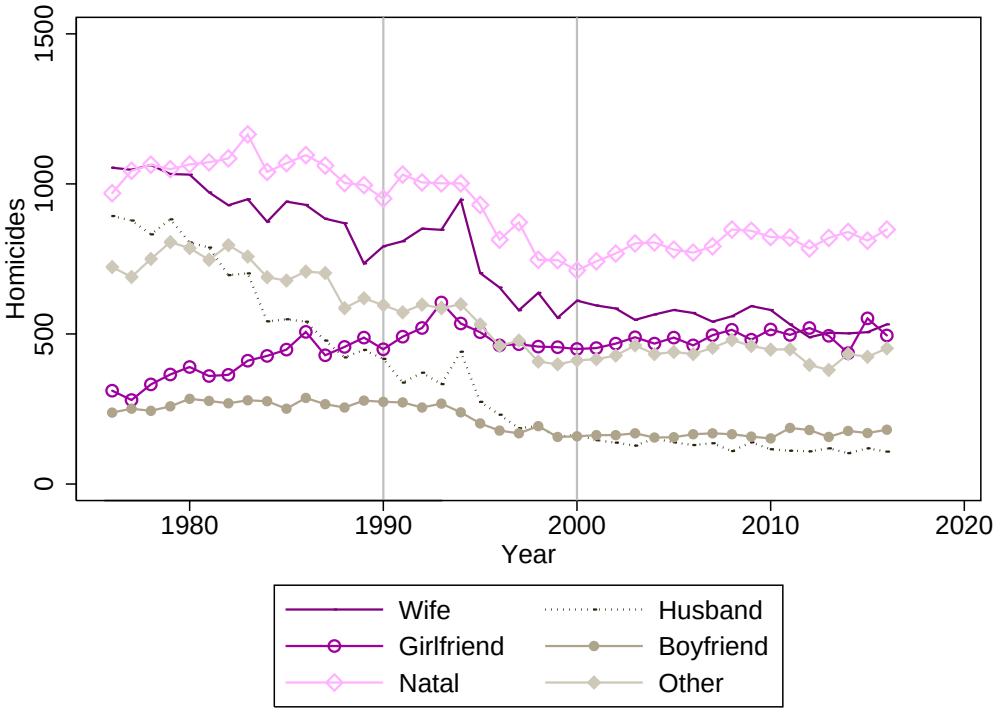
Figure 12: Homicides by Circumstance: 1976-2016



Notes: For a details on the types of circumstances under each heading, please see Table A2.
The 2001 spike reflects the 2,996 victims of the 9/11 attacks.
Source: Kaplan, Jacob. Uniform Crime Reporting (UCR) Program Data: Supplementary Homicide Reports, 1976-2016. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2018-06-19. `https://doi.org/10.3886/E100699V5`



(a) Victim Relation to Offender: 1976-2016



(b) Family Victims: 1976-2016

Figure 13: Homicides by relationship

Source: Kaplan, Jacob. Uniform Crime Reporting (UCR) Program Data: Supplementary Homicide Reports, 1976-2016. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2018-06-19. https://doi.org/10.3886/E100699V5

Notes to Figure 13: For a details on the types of circumstances under each heading, please see Table A3.
The 2001 spike reflects the 2,996 victims of the 9/11 attacks.

Table 1: Key Modern Mobile Telephony Events

Year	Description
1973	First prototype cellular phone call from Midtown Manhattan to Bell Labs, NJ, by Martin Cooper of Motorola
1983	First commercial cellular network opened in Chicago and the Baltimore-DC area.
1991	All digital mobile telephony (2G) launched.
1992	First SMS (short message service).
1993	Omnibus Budget Reconciliation Act reallocates (broadband PCS) spectrum from government to private, commercial use. License winners to be chosen by auction.
	AT&T enters the wireless business with purchase of McCaw Cellular Communications.
	Nextel (previously Fleet Call) on-line L.A. market.
1994	First FCC spectrum auction.
	The Motorola MicroTAC Elite, GSM-compatible and TDMA/Dual-Mode phone introduced. It retailed for around $600 – substantially cheaper than the 1989 version which had retailed at between $2,495 and $3,495.
	First prepaid wireless service introduced by Houston Cellular Telephone Company.
1995	The Nokia 2190 GSM phone was made available on Pacific Bell Mobile Services and Powertel's network.
	Sprint Spectrum – first commercial PCS system – goes on line.
	McCaw invests in Nextel.
1996	Telecommunications Act of 1996.
1998	Cellular telephony included in the CPI.
	First flat-rate plan with national coverage introduced by AT&T: Digital One Rate.
2000	Subscribers pass 100 million mark, up from five million in 1990.
2003	BlackBerry introduces first "smartphone," a phone that could receive and send emails on the go.
2007	iPhone introduced.

Table 2: Mean Antenna Density and Homicide Rates by County Type and Year

	Year				
County type	1970	1980	1990	2000	2010
Main CSA					
Homicide[a]	11.87	19.62	17.27	9.53	8.48
Antenna[b]	9.46	13.63	20.12	30.19	35.81
N	178	179	179	179	179
CSA					
Homicide	8.34	13.34	11.92	6.49	5.84
Antenna	8.42	11.83	17.35	26.66	31.89
N	1142	1144	1149	1149	1148
Not CSA					
Homicide	6.33	9.12	8.01	5.21	4.77
Antenna	1.65	2.98	5.78	10.76	14.49
N	1951	1954	1951	1953	1953
All USA (contig.)					
Homicide	7.87	12.30	10.98	6.18	5.59
Antenna	6.82	9.66	14.57	22.86	27.73
N	3093	3098	3100	3102	3101

Population weighted county means.
[a] – Homicides per 100,000 population. Source: NCHS.
[b] – Sum of antenna structure shares/1000 square miles; antenna structures 200ft or taller within 20 miles of the county centroid; county area is the land area. Source: FCC.
To correct for the some 3,000 homicides in connection to the September 11, 2001 attacks, we replace the homicide counts for Manhattan, Arlington and Somerset County with the average of the flanking years 2000 and 2002.

Table 3: Homicide rate on Antenna Structure Density

	Dependent Variable: Homicide rate Sample: All Counties, 1970-2009 Antenna Structure Measure:						
	Share[a]	Share	Share	Share	Share	Sum[b]	Share-bis[c]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Antennas	0.067***	0.080***	-0.052***	-0.097***	-0.097**	-0.020***	-0.025***
	(0.001)	(0.001)	(0.001)	(0.003)	(0.039)	(0.007)	(0.009)
N	120,930	120,930	120,930	120,930	120,930	120,930	120,930
R^2	0.063	0.134	0.744	0.842	0.842	0.843	0.842
$\bar{y}$	8.754	8.754	8.754	8.754	8.754	8.754	8.754
$\bar{x}$	16.531	16.531	16.531	16.531	16.531	71.397	32.705
Year FE		Yes	Yes	Yes	Yes	Yes	Yes
County FE			Yes				
County-Decade FE				Yes	Yes	Yes	Yes
Cluster					County	County	County

Source: NCHS, FCC.
All regressions are population weighted. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
Year 1989 is missing.
[a] – Sum of antenna structure shares/1000 square miles; antenna structures 200ft or taller within 20 miles of the county centroid; county area is the land area.
[b] – The sum of all antenna structures, 200ft or taller, within 20 miles of the county centroid centroid (per 1000 square mile).
[c] – As for Share, but without height restriction.
To correct for the some 3,000 homicides in connection to the September 11, 2001 attacks, we replace the homicide counts for Manhattan, Arlington and Somerset County with the average of the flanking years 2000 and 2002.

Table 4: Homicides/100,000 Population on Antenna Structure Density

	Dependent Variable: Homicide rate						
	Sample:						
					Counties:		
	1970s	1980s	1990s	2000s	Main CSA	All CSA	Non-CSAs
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Antenna[a]	-0.020	-0.139	-0.151**	-0.001	-0.117***	-0.103**	-0.023
	(0.114)	(0.089)	(0.061)	(0.018)	(0.039)	(0.043)	(0.018)
N	30,955	27,922	31,034	31,019	6,978	44,740	76,190
R^2	0.795	0.847	0.855	0.848	0.899	0.889	0.597
$\bar{y}$	9.150	10.531	9.710	6.325	13.620	9.353	6.868
$\bar{x}$	7.912	11.576	17.381	25.593	22.081	19.509	7.162
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County-Decade FE					Yes	Yes	Yes
Cluster	County	County	County	County	County	County	County

See notes to Table 3.

Table 5: Homicide rate on Antenna Structure Density

	Homicides/100,000 Population				
	Sample: 1990s				
	Main CSA counties		All CSA counties		
	(1)	(2)	(3)	(4)	(5)
	Dependent Variable:				
	A. Homicide[b] Rate				
Antenna[a]	-0.200**	-0.067***	-0.156**	-0.150***	-0.154**
	(0.083)	(0.022)	(0.068)	(0.058)	(0.063)
R^2	0.914	0.972	0.890	0.911	0.920
$\bar{y}$	14.976	14.976	10.433	10.433	10.433
	B. Employment[b] Rate				
Antenna	0.010	-0.054***	-0.009	-0.005	-0.005
	(0.030)	(0.008)	(0.015)	(0.015)	(0.016)
R^2	0.962	0.992	0.962	0.977	0.980
$\bar{y}$	61.552	61.552	61.619	61.619	61.619
	C. OD[c] Rate				
Antenna	-0.011	0.030***	0.023	0.018	0.019
	(0.027)	(0.008)	(0.028)	(0.024)	(0.026)
R^2	0.865	0.943	0.804	0.838	0.858
$\bar{y}$	7.384	7.384	5.897	5.897	5.897
$\bar{x}$	23.739	23.739	20.592	20.592	20.592
N	1,790	1,790	11,490	11,490	11,490
CSA-specific:					
Quadratic trend		Yes		Yes	
Year FE					Yes

All regressions include year and county fixed effects and are population weighted. Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

[a] – Sum of antenna structure shares/1000 square miles; antenna structures 200ft or taller within 20 miles of the county centroid; county area is the land area.

[b] Source: BLS. `https://www.bls.gov/lau/#cntyaa`.

[c] Source: NCHS.

Table 6: Homicides on Antennas – by Circumstance

	Homicide by Circumstance/100,000 Population				
	Sample: CSA Counties covered by Special Homicide Reports (SHR) Years: 1990s				
	Main CSA counties		All CSA counties		
	(1)	(2)	(3)	(4)	(5)
	A. Total Homicides (from Vital Statistics (NCHS))				
Antenna[a]	-0.063	-0.070***	-0.057	-0.082**	-0.082**
	(0.056)	(0.021)	(0.037)	(0.033)	(0.033)
R^2	0.922	0.973	0.909	0.930	0.930
$\bar{y}$	14.31	14.31	10.50	10.50	10.50
	B. Narcotics-Gang (from SHR)[b]				
Antenna	-0.016	-0.035***	-0.023	-0.031**	-0.031**
	(0.021)	(0.010)	(0.015)	(0.013)	(0.013)
R^2	0.755	0.920	0.749	0.819	0.819
$\bar{y}$	1.77	1.77	1.14	1.14	1.14
	C. Argument (from SHR)				
Antenna	-0.030	-0.015*	-0.042**	-0.042***	-0.042***
	(0.021)	(0.008)	(0.017)	(0.016)	(0.016)
R^2	0.828	0.925	0.795	0.832	0.832
$\bar{y}$	3.62	3.62	2.56	2.56	2.56
	D. Theft (from SHR)				
Antenna	-0.030*	-0.020***	-0.023*	-0.025**	-0.025**
	(0.017)	(0.003)	(0.013)	(0.010)	(0.010)
R^2	0.760	0.897	0.728	0.772	0.772
$\bar{y}$	1.49	1.49	0.98	0.98	0.98
	E. Miscellaneous (from SHR)				
Antenna	-0.003	-0.009	-0.006	-0.007	-0.007
	(0.007)	(0.007)	(0.005)	(0.006)	(0.006)
R^2	0.590	0.749	0.591	0.662	0.662
$\bar{y}$	2.67	2.67	2.03	2.03	2.03
	F. Undetermined or No SHR report (Panel A minus Panels B-E)[c]				
Antenna	0.016	0.010	0.038	0.023	0.023
	(0.071)	(0.026)	(0.054)	(0.047)	(0.047)
R^2	0.856	0.925	0.800	0.832	0.832
$\bar{y}$	4.75	4.75	3.80	3.80	3.80
$\bar{x}$	28.93	28.93	21.50	21.50	21.50
N	1,508	1,508	7,330	7,330	7,330
CSA-specific:					
Quadratic trend		Yes		Yes	
Year FE					Yes

See separate page for notes.

Table 7: Homicides by Victim Relationship to Offender

	Homicide by Relationship to Offender/10M Population				
	Sample: Special Homicide Reports, 1990s				
	Main CSA counties		All CSA counties		
	(1)	(2)	(3)	(4)	(5)
	A. Stranger[b]				
Antenna[a]	-0.428	-2.846**	-1.644	-2.227**	-2.227**
	(1.584)	(1.216)	(1.069)	(0.909)	(0.999)
R^2	0.684	0.802	0.700	0.744	0.807
$\bar{y}$	229.58	229.58	150.46	150.46	150.46
	B. Friends and Acquaintances				
Antenna	1.679	-1.665**	-2.373	-2.881*	-2.879
	(2.190)	(0.708)	(1.887)	(1.537)	(1.752)
R^2	0.793	0.904	0.758	0.810	0.847
$\bar{y}$	374.89	374.89	274.28	274.28	274.28
	C. Family				
Antenna	-0.154	-0.722*	-0.531	-0.680**	-0.681**
	(0.479)	(0.400)	(0.336)	(0.291)	(0.320)
R^2	0.606	0.738	0.493	0.533	0.609
$\bar{y}$	157.56	157.56	135.20	135.20	135.20
	D. Undetermined				
Antenna	-25.748	-1.697	-14.370	-12.766	-13.045
	(17.499)	(1.935)	(12.162)	(8.309)	(9.296)
R^2	0.871	0.958	0.864	0.895	0.907
$\bar{y}$	587.84	587.84	368.26	368.26	368.26
$\bar{x}$	28.93	28.93	21.50	21.50	21.50
N	1,508	1,508	7,330	7,330	7,330
CSA-specific:					
Quadratic trend		Yes		Yes	
Year FE					Yes

See separate page for notes.

Table 8: Homicides by Family Relations

	Within Family Homicide/10M Population				
	Sample: Special Homicide Reports, 1990s				
	Main CSA counties		All CSA counties		
	(1)	(2)	(3)	(4)	(5)
	A. Husband[b]				
Antenna[a]	0.183	0.131	0.037	0.040	0.018
	(0.159)	(0.113)	(0.098)	(0.052)	(0.059)†
R^2	0.419	0.584	0.266	0.310	0.418
$\bar{y}$	14.41	14.41	11.86	11.86	11.86
	B. Wife				
Antenna	0.195*	0.260	0.052	0.007	-0.027
	(0.113)	(0.248)	(0.097)	(0.099)	(0.105)†
R^2	0.345	0.524	0.293	0.328	0.420
$\bar{y}$	33.97	33.97	30.29	30.29	30.29
	C. Boyfriend				
Antenna	0.026	0.064	-0.069	-0.108	-0.123
	(0.069)	(0.083)	(0.061)	(0.071)	(0.084)
R^2	0.378	0.535	0.269	0.319	0.440
$\bar{y}$	12.10	12.10	9.65	9.65	9.65
	D. Girlfriend				
Antenna	-0.092	-0.310***	-0.152*	-0.181**	-0.179**
	(0.125)	(0.104)	(0.089)	(0.077)	(0.085)
R^2	0.302	0.472	0.266	0.300	0.413
$\bar{y}$	24.93	24.93	21.85	21.85	21.85
	E. Natal Family				
Antenna	-0.425**	-0.875***	-0.319**	-0.254*	-0.245
	(0.197)	(0.146)	(0.159)	(0.151)	(0.167)
R^2	0.325	0.489	0.271	0.308	0.425
$\bar{y}$	46.13	46.13	40.02	40.02	40.02
	F. Other Family				
Antenna	-0.040	0.007	-0.081	-0.185	-0.126
	(0.124)	(0.174)	(0.091)	(0.129)	(0.137)
R^2	0.364	0.529	0.280	0.318	0.421
$\bar{y}$	26.03	26.03	21.53	21.53	21.53
$\bar{x}$	28.93	28.93	21.50	21.50	21.50
N	1,508	1,508	7,330	7,330	7,330
CSA-specific:					
Quadratic trend		Yes		Yes	
Year FE					Yes

See separate page for notes.

Notes to Tables 6-8.

Source: Supplementary Homicide Reports. https://doi.org/10.3886/E100699V5

The sample is restricted to counties for which a homicide was reported on in the Special Homicide Reports (SHR). Franklin county, OH, home to Columbus, OH, was excluded because the number of homicides reported in the SHR were double those reported in the NCHS's Vital Statistics. This exclusion does not affect the results.

The population denominator is the county population.

The SHR does not disaggregate by borough the homicides in New York City. All city homicides are "given" to Manhattan, an allocation we keep (thus the main CSA county sample includes the whole of New York City). To accommodate this assignment, for the antenna density structure measure we use the population weighted mean for the five boroughs. Excluding New York City does not change the qualitative results.

All regressions include county and year fixed effects and are population weighted. Robust standard errors clustered at the county level in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

† – standard errors clustered at the CSA rather than the county level (in the latter case, standard errors would not compute).

[a] – Sum of antenna structure shares/1000 square miles; antenna structures 200ft or taller within 20 miles of the county centroid; county area is the land area.

[b] – For detailed breakdowns of categories, see Appendix Tables A2 and A3.

[c] – Number of homicides without a determined circumstance, either because there was not an SHR report or the SHR report left circumstance "undetermined."

References

Anna Aizer and Janet Currie. Lead and juvenile delinquency: New evidence from linked birth, school and juvenile detention records. Working Paper 23392, National Bureau of Economic Research, May 2017. URL http://www.nber.org/papers/w23392.

Jefferson D. P. Bertoloai and Luiz G.D.S. Scorzafave. 'property rights' in illicit drug markets. Technical report, FEARP-USP, 2018.

Bureau of Justice Statistics. The nation's two measures of homicide. Program Report NCJ 247060, US Department of Justice, 2014. URL https://www.bjs.gov/content/pub/pdf/ntmh.pdf.

Shawn Bushway, Matthew Phillips, and Philip J. Cook. The overall effect of the business cycle on crime. *German Economic Review*, 13(4):436–446, November 2012.

Anne Case and Angus Deaton. Rising Morbidity and Mortality in Midlife among White Non-Hispanic Americans in the 21st Century. *Proceedings of the National Academy of Sciences*, 112(49):15078–15083, 2015.

Aaron Chalfin and Justin McCrary. Criminal deterrence: A review of the literature. *Journal of Economic Literature*, 55(1):5–48, March 2017.

Scott H Decker and G. David Curry. Gangs, gang homicides, and gang loyalty: Organized crimes or disorganized criminals. *Journal of Criminal Justice*, 30(4):343 – 352, 2002.

Melissa Dell. Trafficking networks and the Mexican drug war. *American Economic Review*, 105(6):1738–1779, June 2015.

Jeff Desimone. The effect of cocaine prices on crime. *Economic Inquiry*, 39(4):627 – 643, 2001.

Rebecca Diamond. The determinants and welfare implications of US workers' diverging location choices by skill: 1980-2000. *American Economic Review*, 2016.

Rafael Dix-Carneiro, Rodrigo R. Soares, and Gabriel Ulyssea. Economic shocks and crime: Evidence from the Brazilian trade liberalization. *American Economic Journal: Applied*, Forthcoming.

John J Donohue and Steven D Levitt. The impact of legalized abortion on crime over the last two decades. Working Paper 25863, National Bureau of Economic Research, May 2019.

John J. III Donohue and Steven D. Levitt. The impact of legalized abortion on crime. *Quarterly Journal of Economics*, 116(2):379–420, May 2001.

Lena Edlund, Cecilia Machado, and Maria Sviatschi. Bright minds, big rent: Gentrification and the rising returns to skill. Working Paper CES-WP-16-36R, US Census Bureau Center for Economic Studies, November 2016. URL https://www2.census.gov/ces/wp/2016/CES-WP-16-36.pdf.

William N Evans, Craig Garthwaite, and Timothy J Moore. Guns and violence: The enduring impact of crack cocaine markets on young black males. Working Paper 24819, National Bureau of Economic Research, July 2018.

Federal Communications Commission. Second annual report and analysis of competitive market conditions with respect to commercial mobile services. Report 97-75, FCC, 1997. URL https://us-fcc.app.box.com/s/rkxvsg39h7o7fzf1p2xjmq91d5pq6o5g.

Christopher Foote and Christopher Goetz. The impact of legalized abortion on crime: Comment. *Quarterly Journal of Economics*, 123(1), February 2008.

R. Terry Furst, Richard S. Curtis, Bruce D. Johnson, and Douglas S. Goldsmith. The rise of the street middleman/woman in a declining drug market. *Addiction Research*, 7(2):103, 1999. ISSN 10586989. URL https://ezproxy.cul.columbia.edu/login?qurl=https%3a%2f%2fsearch.ebscohost.com%2flogin.aspx%3fdirect%3dtrue%26db%3dsih%26AN%3d4004448%26site%3dehost-live%26scope%3dsite.

Eric D. Gould, Bruce A. Weinberg, and David B. Mustard. Crime rates and local labor market opportunities in the United States: 1979-1997. *Review of Economics and Statistics*, 84(1):45 – 61, 2002.

Jeff Grogger and Michael Willis. The emergence of crack cocaine and the rise in urban crime rates. *Review of Economics and Statistics*, 82(4):519–529, November 2000.

Jerry Hausman. Celluar telephone, new products, and the CPI. *American Statistical Association*, 17(2):188–194, April 1999.

Thomas W. Hazlett. U.S. wireless auctions. Technical report, George Mason University, 1999. URL www.accc.gov.au/system/files/Hazlett%2C%20Thomas%20%28Auctions%20Paper%29.pdf.

James C. Howell and Scott H. Decker. The youth gangs, drugs, and violence connection. *Juvenile Justice Bulletin*, January 1999. US Department of Justice.

Hawre Jalal, Jeanine M. Buchanich, Mark S. Roberts, Lauren C. Balmert, Kun Zhang, and Donald S. Burke. Changing dynamics of the drug overdose epidemic in the united states from 1979 through 2016. *Science*, 361(6408), 2018. ISSN 0036-8075. doi: 10.1126/science.aau1184.

Bruce D Johnson. Patterns of drug distribution: implications and issues. *Substance use and misuse*, 38(11-13):1789–1806, 2003.

Bruce D. Johnson, Andrew Golub, and Elo ise Dunlap. The rise and decline of hard drugs, durg markets, and violence in inner-city new york. In Alfred Blumstein and Joel Wallman, editors, *The Crime Drop in America*, chapter 6. Cambridge University Press, 2000.

Danielle Kaeble and Mary Cowhig. Correctional populations in the united states, 2016. Ncj 251211, U.S. Department of Justice: Office of Justice Programs, April 2018. URL https://www.bjs.gov/content/pub/pdf/cpus16.pdf.

Jonathan Klick, John MacDonald, and Thomas Stratmann. Mobile phones and crime deterrence: An underappreciated link. In Alon Harel and Keith N. Hylton, editors, *Research Handbook on the Economics of Criminal Law*. Edward Elgar Publishing, 2002. doi: http://dx.doi.org/10.2139/ssrn.2130234.

Iliana Kuziemko and Steven Levitt. An empirical analysis of imprisoning drug offenders. *Journal of Public Economics*, 88(9-10):2043–2066, August 2004.

SD Levitt and SA Venkatesh. An economic analysis of a drug-selling gang's finances. *Quarterly Journal of Economics*, 115(3):755–789, Aug 2000.

Steven D. Levitt. Understanding why crime fell in the 1990s: Four factors that explain the decline and six that do not. *Journal of Economic Perspectives*, 18(1):163–190, Win 2004.

Ballesteros MF Mack KA, Jones CM. Illicit drug use, illicit drug use disorders, and drug overdose deaths in metropolitan and nonmetropolitan areas - United States. Morbidity and mortality weekly report: Surveillance summaries, Centers for Disease Control and Prevention, October 20 2017.

Maltz. Bridging gaps in police crime data. Bureau Justice Statistics Discussion Paper NCJ 176365, U.S. Department of Justice, September 1999.

Walter B. Miller. The growth of youth gang problems in the United States: 1970-98. OJJDP report, U.S. Department of Justice, 2001.

Carlo Morselli, Masarah Paquet-Clouston, and Chloé Provost. The independent's edge in an illegal drug distribution setting: Levitt and Venkatesh revisited. *Social Networks*, 51(Supplement C):118 – 126, 2017. ISSN 0378-8733. Crime and Networks.

James B. Murray. *Wireless Nation: The Frenzied Launch of the Cellular Revolution in America*. Perseus Publishing, Cambridge, 2001.

National Gang Intelligence Center. 2015 national gang report. Technical report, FBI, Washington, DC, 2013.

Brendan O'Flaherty and Rajiv Sethi. Urban crime. In J. Vernon Henderson Gilles Duranton and William C. Strange, editors, *Handbook of Regional and Urban Economics*, volume 5B, pages 1519–1621. North Holland, Amsterdam, 2015.

Erin A. Orrick and Alex R. Piquero. Were cell phones associated with lower crime in the 1990s and 2000s? *Journal of Crime and Justice*, 38(2):222–234, 2015.

Amy Peacock, Janni Leung, Sarah Larney, Samantha Colledge, Matthew Hickman, Jurgen Rehm, Gary A. Giovino, Robert West, Wayne Hall, Paul Griffiths, Robert Ali, Linda Gowing, John Marsden, Alize J. Ferrari, Jason Grebely, Michael Farrell, and Louisa Degenhardt. Global statistics on alcohol, tobacco and illicit drug use: 2017 status report. *Addiction*, 113(10):1905–1926, 2018.

David C. Pyrooz and Gary Sweeten. Gang membership between ages 5 and 17 years in the United States. *Journal of Adolescent Health*, 56(4):414–419, 4 2015. ISSN 1054-139X.

Peter Reuter. *The Organization of Illegal Markets: An Economic Analysis*. University of Michigan Library, 1985.

Jessica Wolpaw Reyes. Environmental policy as social policy? The impact of childhood lead exposure on crime. *B E Journal of Economic Analysis & Policy*, 7(1), 2007.

Oliver Roeder, Lauren-Brooke Eisen, and Julia Bowling. What caused the crime decline? Research report, The Brennan Center for Justice at NYU School of Law, 2015.

Christopher J. Ruhm. Taking the measure of a fatal drug epidemic. Working Paper 22504, National Bureau of Economic Research, August 2016.

Christopher J. Ruhm. Deaths of despair or drug problems? Working Paper 24188, National Bureau of Economic Research, January 2018.

P. Seth, L. Scholl, R.A. Rudd, and S. Bacon. Overdose deaths involving opioids, cocaine, and psychostimulants – United States, 2015-2016. Morbidity and mortality weekly report, Centers for Disease Control and Prevention, March 29 2018.

Rajiv Sethi and Brendan O'Flaherty. Homicide in black and white. *Journal of Urban Economics*, 68:215–230, 11 2010.

Betsey Stevenson and Justin Wolfers. Bargaining in the shadow of the law: Divorce laws and family distress. *Quarterly Journal of Economics*, 121(1):267–288, 2006.

Charles Tilly. *Coercion, Capital and European States, A.D. 990 - 1992*. Blackwell, 1995 edition, 1990.

Jan C. van Ours and Ben Vollaard. The engine immobiliser: A non-starter for car thieves. *The Economic Journal*, 126(593):1264–1291, 2016.

A1 Appendix Tables

Table A1: Robustness to State-year level FE or Abortion Rate

	Homicides/100,000 Population				
	Sample: 1990s				
	Main CSA counties		All CSA counties		
	(1)	(2)	(3)	(4)	(5)
	0. Antenna (from Table 5)				
Antenna[a]	-0.200**	-0.067***	-0.156**	-0.150***	-0.154**
	(0.083)	(0.022)	(0.068)	(0.058)	(0.063)
R^2	0.914	0.972	0.890	0.911	0.920
	A. Antenna + State-year FE				
Antenna	-0.171	-0.065***	-0.135**	-0.119**	-0.121**
	(0.105)	(0.022)	(0.054)	(0.048)	(0.052)
R^2	0.955	0.983	0.918	0.928	0.933
	B. Antenna + Effective Abortion Rate				
Antenna	-0.171**	-0.066***	-0.145**	-0.144***	-0.146**
	(0.073)	(0.023)	(0.059)	(0.054)	(0.058)
Abortion[b]	-3.817***	-1.968	-2.308***	-6.013**	-7.193**
	(0.708)	(2.230)	(0.447)	(3.002)	(3.503)
R^2	0.916	0.971	0.890	0.913	0.923
N	1,790	1,790	11,490	11,490	11,490
Mean					
Homicide	14.976	14.976	10.433	10.433	10.433
Antenna	23.739	23.739	20.592	20.592	20.592
Abortion	0.974	0.974	1.035	1.035	1.035
CSA-specific:					
Quadratic trend		Yes		Yes	
Year FE					Yes

All regressions include year and county fixed effects and are population weighted. Robust standard errors, clustered at the county level, in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
[a] – Sum of antenna structure shares/1000 square miles; antenna structures 200ft or taller within 20 miles of the county centroid; county area is the land area.
[b] – Effective abortion rate for homicides crimes, curtesy of John Donohue and Steven Levitt. For a description of this state-year level variable, see Donohue and Levitt [2019]. The 1990-1999 change in this variable was 1.36 (unweighted mean, 51 states).
Also see notes to Table 3.

Table A2: Homicide Circumstance – Contiguous US, 1976-2016

Description	Incidents	Victims	percent
Narcotics-Gang	56,675	60,074	8.3
[Violation of] narcotic drug laws	25,446	27,339	3.8
Juvenile gang killings	22,635	23,609	3.3
Brawl due to influence of narcotics	4,532	4,799	0.7
Gangland killings	4,062	4,327	0.6
Argument	205,966	212,360	29.3
Other arguments	191,686	197,635	27.2
Argument over money or property	14,280	14,725	2.0
Theft	63,912	67,160	9.3
Robbery	56,127	58,890	8.1
Burglary	5,901	6,283	0.9
Larceny	1,175	1,252	0.2
Motor vehicle theft	709	735	0.1
Miscellaneous	183,620	197,923	27.3
Other non-felony type homicide	86,352	92,432	12.7
Other – not specified	13,333	17,284	2.4
Felon killed by police	15,550	15,698	2.2
Brawl due to influence of alcohol	14,987	15,381	2.1
All suspected felony type	12,402	13,105	1.8
Felon killed by private citizen	11,685	11,900	1.6
Lovers triangle	10,141	10,812	1.5
Arson	2,903	4,547	0.6
Rape	4,051	4,158	0.6
All other manslaughter by negligence	2,977	3,144	0.4
Other negligent handling of gun	2,312	2,316	0.3
Other sex offense	1,395	1,441	0.2
Child killed by babysitter	1,235	1,243	0.2
Gambling	1,016	1,061	0.1
Institutional killings	1,018	1,035	0.1
Children playing with gun	868	868	0.1
Prostitution and commercialized vice	575	599	0.1
Sniper attack	470	547	0.1
Victim shot in hunting accident	250	252	0.0
Gun-cleaning death – other than self	90	90	0.0
Abortion	10	10	0.0
Undetermined	179,933	188,348	25.9
Total	690,106	725,865	100.0

Source: Kaplan, Jacob. Uniform Crime Reporting (UCR) Program Data: Supplementary Homicide Reports, 1976-2016. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2018-06-19. `https://doi.org/10.3886/E100699V5`
Note: Frequencies are for the first victim.

Table A3: Homicide Relationship – Contiguous US, 1976-2016

Description	Incidents	Victims	Percent
Stranger	108,317	115,809	16.0
Friends and Acquaintances	209,416	218,645	30.1
Friend	24,704	25,439	3.5
Acquaintance	143,481	149,397	20.6
Employee	387	439	0.1
Employer	514	575	0.1
Homosexual Relationship	1,606	1,626	0.2
Neighbor	7,312	7,824	1.1
Other Known to Victim	31,412	33,345	4.6
Wife	28,519	29,806	4.1
Wife	25,374	26,595	3.7
Common-Law Wife	3,145	3,211	0.4
Husband	14,152	14,226	2.0
Husband	11,479	11,547	1.6
Common-Law Husband	2,673	2,679	0.4
Boyfriend	8,588	8,615	1.2
Girlfriend	18,115	18,724	2.6
Natal Family	32,657	36,898	5.1
Son	9,747	10,975	1.5
Daughter	7,043	8,202	1.1
Brother	6,085	6,346	0.9
Father	4,771	5,140	0.7
Mother	4,274	4,780	0.7
Sister	1,237	1,455	0.2
Other Family	20,906	22,620	3
In-Law	4,289	4,685	0.6
Ex Wife	2,125	2,311	0.3
Stepfather	1,618	1,675	0.2
Stepson	1,319	1,418	0.2
Ex Husband	853	859	0.1
Stepdaughter	719	852	0.1
Stepmother	219	258	0.0
Other	9,764	10,562	1.5
Undetermined	248,936	260,522	35.9
Total	690,106	725,865	100.0

Source: Kaplan, Jacob. Uniform Crime Reporting (UCR) Program Data: Supplementary Homicide Reports, 1976-2016. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2018-06-19. `https://doi.org/10.3886/E100699V5`
Note: Frequencies are for the first victim and the first offender.

A2 Appendix – Antenna Structures – FCC

The Antenna Structure Registration data were downloaded from:
`http://wireless.fcc.gov/uls/index.htm?job=transaction&page=weekly`

We match the latitude and longitude information to the nearest county centroid reflecting county boundaries as of 2000, obtained from:
`http://www.census.gov/tiger/tms/gazetteer/county2k.txt`

A3 Appendix – Mortality data – National Center for Health Statistics (NCHS)

The NCHS data corresponds to the data available on death certificates and are thus the most complete data on deaths in the US.

An advantage of the NCHS data is that the five New York City boroughs are reported separately with respect to occurrence (deaths can also be by residence).

The NCHS data include place of occurrence and place of residence. We restrict the data to US residents and for location we use place of occurrence.

The NCHS data only contain information from some 400 counties in 1989 and therefore we exclude that year.

For year 1972, only half of deaths were included and therefore we multiply deaths in that year by two.

A4 Appendix – Population data – Census

We used the Census' county level population estimates, available at

`https://www.census.gov/programs-surveys/popest/data/data-sets.All.html`

A5 Appendix – Homicide data – Special Homicide Reports

The data `shr_1976_2016.csv` version V5[2018-06-19] can be downloaded from:
`https://www.openicpsr.org/openicpsr/project/100699/version/V5/view`

For a description of the variables in the SHR, please see:
`https://ucr.fbi.gov/nibrs/addendum-for-submitting-cargo-theft-data/shr` Participation in the SHR is voluntary and not all agencies report.

An agency is identified by its ORI(ginating agency) number.

Each row is an incident, and the ORI, year, month and incident number identifies each incident. Each incident can have several homicide victims and several offenders.

A couple of adjustments were made.

First, when the National Center for Health Statistics reported zero homicides for a county and the SHR did not have any reported homicides, we assumed a zero homicide rate for that county in the SHR data as well, on the assumption that NCHS would typically have the "correct" number and that zero homicides is plausible reason for the corresponding SHR data to be missing.

Second, homicide data for New York City are not disaggregated to the county level. Therefore, for this data set, we exclude New York City.

Third, there were a few duplicate observations (roughly 350), looking over them, some of them were "adjustments", for those we used the adjusted record.

A5.1 Circumstance

The circumstances are coded for all offenders, for detailed categories see Table A2.

In the cases of multiple offenders (4 percent of incidents and 9 percent of victims), in more than 98 percent of the cases with more than one offender, only one circumstance was given (i.e., the same circumstance was stated for all offenders).

In cases with multiple circumstances, the priority was as follows:

Narcotics-Gang > Theft > Argument > Miscellaneous >Undetermined

A5.2 Relation

For detailed categories see Table A3. This information is only available for victim 1. If a husband kills his wife and n other people, we count all n homicides as being of this type although only victim 1 was killed by her husband.

In case of multiple victims, we apply the same relationship for the first victim to all victims. While somewhat arbitrary, these additional victims may be viewed as collateral damage swept up by the primary conflict.

There is information on up to 11 offenders. For instance, for a woman murdered by her husband and a friend, the first relationship variable might be codes as husband and the second as friend. We created two indicator variables, one which indicates all homicides in which a relationship, say friend, was mentioned, and one which assigns only one relationship to each incident. In practise, these two measures yielded almost identical results and therefore we went with the measure that assigns a unique relationship so as to avoid double counting.

To assign a unique relationship, relationships need to be prioritized. In the above example, the victim was a wife and a friend. We prioritize "closeness" resulting in the following order of priority:

Husband, wife >Family-Natal > Boyfriend, girlfriend > Family-Other > Friends and acquaintances > Strangers > Undetermined.