Offenders under Watch: A Quasi-Experimental Analysis of Camera Surveillance and Criminal Behavior*

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Abstract

Does camera surveillance deter crime? A decade of empirical and theoretical exploration has failed to reach a consensus on the effect of camera surveillance on crime rates. Rational Choice Theory predicts that offenders under surveillance will choose not to commit a crime given the heightened riskiness associated with breaking the law, causing a localized decline in crime. I expand this theoretical framework through a game-theoretic interaction between police and offenders. Following surveillance implementation, police will reallocate away from the surveilled block, decreasing the equilibrium level of a crime in a fashion that does not manifest as a local treatment effect. The empirical analysis of this paper, using quasi-experimental matching methodologies, confirms that there is no local treatment effect of surveillance. These findings call for future research on general equilibrium effects in criminology as well as for randomized evaluations.

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1 Introduction

Since the late 1980s, crime in the United States has declined sharply. Violent crime rates have declined by 23% and property crime rates by 33% over the past two decades even as the U.S. population has increased steadily over this period (see Figures 1 and 2). Metropolises such as New York, Chicago, and Los Angeles have witnessed homicides drop to levels not seen since the 1960s. (Langan 2004, 2).

These declines, however, have not been uniformly distributed across the U.S. Mid-sized cities have also seen crime rates fall, but to a sizably smaller extent than their larger counterparts. For instance, New York City alone contributed to nearly three-quarters of the nationwide crime drop from 1994-95 (Glazer). But these mid-sized cities were the first in the U.S. to embrace a new and promising technology in law enforcement: video surveillance. By 1997, the California Research Bureau estimated that 13 municipalities in the U.S. had installed surveillance systems operated by state or local law enforcement agencies; of these, 11 had populations of less than 750,000 (Nieto 1997).

Today, that dichotomy in the prevalence of surveillance in larger versus smaller cities is no longer the case. Washington, D.C. recently incorporated cameras from the public school system and the D.C. Housing Authority into its police-monitored arsenal, bringing the total number of cameras in that city to an estimated 4,800 (Sheridan). Chicago's Mayor Richard Daley, Jr., said in February 2009 that he will push for a camera on "almost every block" by 2016 (Spielman)—adding to an existing system that also numbers over 4,000 cameras. According to a study by the New York Civil Liberties Union, New York City now has installed 300 law enforcement cameras over Manhattan, though that city, too, intends to expand the scope of its surveillance program ("Who's Watching?").

Mid-sized urban areas also continue to adopt the technology into their law enforcement arsenals, particularly as they face higher rates of violent crime than most major metropolises (*Crime in the U.S.* 2007). Among these new surveillance cities are Fresno, California; Newark, New Jersey; Milwaukee, Wisconsin; Indianapolis, Indiana; Baltimore, Maryland; Grand Rapids, Michigan; Durham, North Carolina; Denver, Colorado; St. Petersburg, Florida; and Athens, Georgia. In Austin, Texas, the mayor announced that he plans to install ubiquitous, around-the-clock surveillance by the end of 2009 (Johnson). Overall, surveillance is proliferating rapidly: A 2006 study estimated that there are more than one million cameras currently operating in the U.S. (Nestel, 2006).

But these cameras do not multiply without controversy. In particular, doubts remain as to the effectiveness of surveillance in deterring criminal activity. Law enforcement officials in many U.S. cities argue that cameras do deter crime (for example, Baltimore police estimate that violent crime is down by more than 15% in areas covered by their CitiWatch cameras), but independent statistical evaluations are less certain—not least because only three such studies have been conducted in the U.S.

This essay analyzes the effect of video surveillance on crime rates in a mid-sized city in the U.S. The analytical challenge of this paper is to disentangle the effects of other crime reduction initiatives often operating simultaneously and within the same areas, as well as to remove bias from endogenized camera placement. Using quasi-experimental methodologies that attempt to control for differential selection, I measure the impact of surveillance on overall crime rates. I also explore how surveillance affects criminal behavior by looking for evidence of displacement to areas surrounding the cameras.

I find that, on the whole, surveillance has no local treatment effect on crime levels. Surveillance also does not appear to displace crime to surrounding areas. But I argue through a formal model, based on an extensive form game, that the absence of a local treatment effect is to be expected if police officers efficiently reallocate their resources away from surveilled blocks following the implementation of camera surveillance. The empirical results of the paper are in accordance with the model's prediction that surveillance may not manifest a local treatment effect while still reducing the overall equilibrium level of crime in the city.

The rest of this thesis is organized as follows. In Section 2, I review relevant criminological theories and the findings of existing empirical evaluations of camera surveillance. I also propose a new theory of criminal behavior as an ongoing, strategic interaction between police and offenders, shocked by the exogenous installation of camera surveillance. Section 3 provides background on the surveillance system in question and descriptive statistics of the analysis. I present the empirical strategy in Section 4 and discuss results and threats to inference in Section 5. Section 6 concludes with implications for police and further research.

2 An Overview of the Literature

Most camera surveillance systems are constructed with the intention of reducing criminal offenses—centuries of social control philosophy, as well as modern criminological theories, support this premise. Empirical evaluations, however, have proven inconclusive. This section presents both the theoretical foundations of surveillance and a selection of empirical assessments of surveillance technology. This study's *ex ante* hypothesis—that camera surveillance will reduce crime—finds its basis in rational choice theory, but at the end of this section I propose a previously unexplored alternative, based on game theory, that suggests that camera surveillance may reduce the equilibrium level of crime while not manifesting a local deterrent effect.

2.1 Surveillance and criminal behavior

Modern-day video surveillance draws on a Benthamite principle of uncertainty. Jeremy Bentham's 1785 prescription for the ideal prison system, the Panopticon, specified that individuals were to be always cognizant of the presence of a watching eye ("visible"), yet unable to determine if they were indeed being watched ("unverifiable") (Foucault 1979, 201). The arbitrariness of this authority would condition the prisoners into compliance with authority; with the risks of bad behavior heightened under probable but uncertain surveillance, prisoners would discipline themselves into conforming at all moments.

This self-induced reevaluation of risk is the driving factor behind the modern theory of surveillance. Classical criminology assumes that criminals are rational actors who adjust their behavior according to perceived level of risk, a theory first proposed in 1968 by Gary Becker (and for which Becker won the Nobel Prize in Economics). Freeman (1999) proposed a concise model of this decision-making calculus, which weighs the expected utilities of criminal activity versus legitimate earnings:

$$(1-p)U(W_C) - (p)U(S) > U(W_L)$$

where W_C and W_L are earnings from the criminal and legitimate activity, respectively, S is the extent of punishment (e.g. sentence length), and p is the probability of arrest and conviction. To deter the potential offender away from crime, legitimate activities must pay more than criminal ones, whether by increasing legitimate-market wages, decreasing criminal payoffs, increasing penalties, or increasing the perceived probability of arrest and incarceration.

Cornish and Clarke (1986) offer a fourth variable missing in the Freeman model. Their Rational Choice Theory (RCT) proposes that, in addition to the probability of arrest, severity of punishment, and utility to be gained from the act, rational offenders also consider the *immediacy* of their need for that utility—i.e. they may discount future action (Cornish and Clarke 1968). Unlike Drift Theory or Systematic Crime Theory, RCT argues that crime is not systematic within certain social groups. Instead, offenses occur as the result of utilitarian considerations of a reasoning agent, and with this discounting factor, the question is not "yes or no" to offending, but "now versus later". Ultimately, the immediate features or circumstances of a criminal opportunity will determine the outcome—"yes or no" at this moment—of the offender's decision.

In rejecting deterministic views of criminal offending, RCT opened a new realm for deterrence theory. Clarke (1995) introduces Situational Crime Prevention (SCP), a deterrence paradigm that entails manipulating the environment in which a criminal act will occur through what Clarke calls "opportunity reduction techniques": Increasing the effort needed to commit a crime, reducing anticipated criminal rewards, heightening the perceived probability of arrest and conviction, reducing offender provocations, and removing excuses for offenders (Clarke 1997, 15-

25). These techniques directly influence the parameters of Freeman's model and have become popular deterrence strategies among law enforcement officials and criminologists.

In keeping with this RCT/SCP framework, camera surveillance increases offenders' perceived probability of apprehension in the immediate environment in which they may commit an offense. The causal mechanisms for this probability increase are numerous, and Pawson and Tilley (1997) have offered a comprehensive list of the causal mechanisms behind this increased riskiness of criminal activity.[1] I classify their mechanisms as offender-, police-, and victim-specific and expand the list somewhat.

Offender-specific mechanisms:

1) Increases **probability of arrest**: Officers witness an offense in progress and direct police resources immediately to the scene of the crime.
2) Increases **probability of conviction** given arrest: Video footage provide incriminating evidence in trial.
3) Reduces **duration** of crime: Shorter offenses decrease the risk of being captured on video.
4) Reduces **severity** of crimes: Facing an increased conditional probability of incarceration, offenders hedge against longer sentences and commit less egregious offenses.

[1] Note that their causal mechanisms assume that the police actively monitor surveillance camera feed. Many surveillance systems simply record activity, shifting the relative importance of offender- and police-specific mechanisms and moving the system away from one of proactive deterrence.

5) Enhances offenders' **awareness of policing**: The physical presence of and publicity surrounding the cameras remind offenders of broader community commitment to law enforcement.

Police-specific mechanisms:

1) Improves **efficiency of deployment**: Police target resources to crime scenes more efficiently, adjusting the number of deployed officers based on their evaluations of real-time video feed.
2) Reduces resource **waste**: Police departments save resources by verifying reported offenses and reducing the number of false reports.
3) Improves **clearance and conviction rates**: Better policing statistics signal increased risks to offenders.

Victim-specific mechanisms:

1) Enhances **natural surveillance**: Traffic increases in the surveilled area as visitors feel that the neighborhood is under added watch from law enforcement.
2) Promotes **cautious behavior:** Cameras remind visitors of the risks of the area, encouraging safer or precautionary behaviors.
3) Increases **reporting of crimes**: Residents find support for reporting offenses from the corroborating evidence provided by the camera.

Camera surveillance may therefore contribute to deterrence along two dimensions of classical deterrence theory: general deterrence, by changing the criminal's rational calculus through an increase in the perceived risk of punishment, and incapacitation, by convicting known deviants through surveillance evidence and removing them from the streets.[2]

2.2 Empirical literature on surveillance systems

Existing evaluations of surveillance are consistent only in how inconclusive their findings have proven. Each new survey argues for a different degree or direction of effect, and researchers have rarely reevaluated the same areas. Given the variability inherent in surveillance systems and the lack of an appropriate control group in many papers, there are doubts as to both the internal and external validity of the literature's conclusions. In particular, statistical significance is difficult to achieve in such studies, as observations are often too low to prove that crime reductions associated with surveillance are more than just normal fluctuations in crime (Ratcliffe 2006, 19).

In this section, I elaborate on a small selection of the sizable literature on surveillance. To the best of my knowledge, there have only been three independent evaluations of surveillance systems in the U.S.; while I do speak briefly to a few seminal studies from the UK, I hesitate to generalize more of those evaluations to U.S. programs due to differences in timing, technology, operation, and density between the two countries' surveillance systems.

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[2] The persuasiveness of this entire discussion, however, hinges on an assumption that offenders are aware that they are within the viewshed of a camera (Ratcliffe 2006, 9). I expand upon this theoretical limitation in my discussion of threats to inference in Section VI.

2.2.1 Results from the United Kingdom

The United Kingdom may be the West's most heavily surveilled society. Closed-circuit television (CCTV) surveillance first appeared in Britain in 1986 and had expanded to 300 jurisdictions by 1994 (Nieto 1997, 7). Today, up to 4.2 million cameras are monitoring the country ("Britain is 'surveillance society'"). London alone is estimated to have over 400,000 cameras within its bounds, and a denizen of that city may be captured on film by 300 unique cameras in any given day (McCahill and Norris 2002, 42).

A 2005 report issued by the British Home Office evaluated 13 surveillance systems in the UK (Gill and Spriggs 2005). Only two programs in their sample were associated with a statistically significant crime reduction in intervention areas, and six showed a substantial but statistically insignificant decrease in crime rates—not quite irrefutable evidence of a treatment effect of surveillance. Displacement effects were limited but did occur into immediately adjacent areas or, in towns with high camera density, into the few areas of gaps in coverage. Effect size depended on the context; for example, researchers found that surveillance had a lesser effect on "impulsive crimes", such as those committed under the influence of alcohol, than on premeditated offenses (Gill and Spriggs 2005, 35). The authors also argue that effectiveness varied by the type of camera and its construction and mounting.

Methodologically the report is strong. Wherever possible, the authors evaluate at least one to two years of pre- and post-intervention crime data and use time-series methods to control for seasonality. The overall conclusion of the report, though, is hardly a ringing endorsement of surveillance, and it remains unclear how any deterrent effect of surveillance can be generalized over different contexts or crime types.

Cameron et. al. (2008) examine the findings of 44 individual surveillance evaluations coming out of the U.K., 22 of which had been previously evaluated in a meta-analysis by Welsh and Farrington (2002). The authors report a statistically significant crime reduction in 41% of the evaluations, whereas 43% showed no statistically significant effect. Surveillance systems in parking lots see the greatest rate of success. The authors also analyze five studies in the U.S., none of which show a decrease in crime in areas surrounding surveillance cameras (Cameron et. al. 2008, 15).

Studies in the UK may not generalize well to the U.S. for a number of reasons. Law enforcement surveillance in the U.S. is less prevalent and less publicized than it is in the UK; Offenders may be less aware of surveillance in the U.S., and so effect sizes may lower in the U.S. than in Britain. American systems also operate in a political environment that is slightly more hostile to surveillance for reasons of civil liberties, perhaps affecting the relative occurrence of proactive monitoring. U.S. technology may be newer given its more recent implementation in this country. And surveillance in the U.S. is a local rather than a national effort, contributing to wider variation among systems' funding, management, and technical specifications.

2.2.2 San Francisco, California

From 2005-2008, the San Francisco Mayor's Office launched the Community Safety Camera program, a plan for nearly 80 cameras in high-crime "hot-spots", gang territory, and public housing units throughout the city. The system is not managed by the San Francisco Police Department, but rather by the Department of Emergency Management (King et. al. 2008, 28). Due to acute concerns for civil liberties in the city, the system only passively records, although "the public is likely generally unaware of this fact" (King et. al. 2008, 44). All camera locations include signage that explicitly states that they are under passive surveillance, and individuals and entities within 300 feet of proposed surveillance locations are notified of the camera installation through mailings (King et. al. 2008, 38).

Researchers at the University of California, Berkeley, published an independent evaluation of the San Francisco program in December 2008 (King et. al. 2008). They used quasi-experimental difference-in-differences methods, with control groups as crimes occurring in consecutive, 100' rings from the immediate target location, and crimes occurring indoors within this 1000' buffer. The evaluation finds a statistically significant, 24% decline in property crimes occurring within 100' of the cameras. Reductions in larceny theft drove this decline. There was no deterrent effect for violent crime, homicides, or drug offenses. However, researchers only gained access to data on crimes occurring within 1000' of the cameras. Law enforcement officials also complained that poor image quality and video choppiness limited the usefulness or credibility of video footage as evidence in trial. Camera footage has only been used to charge six suspects since the program's inception in 2005 (King et. al. 2008, 13).

2.2.3 Los Angeles, California

Los Angeles, California, currently has a network of 80 surveillance cameras that are actively monitored by the Los Angeles Police Department. The cameras target not only high-crime areas as in San Francisco, but also major tourist and commercial thoroughfares (Cameron et. al. 2008, 19).

Cameron et. al. (2008) analyze two neighborhoods of the city with a substantial share of the surveillance cameras, a public housing project and a tourist strip along Hollywood Boulevard. According to law enforcement officials, the cameras were constructed in each area for disparate purposes: along Hollywood Boulevard, to reduce property crime and prevent criminal behavior outside of nightclubs and retail establishments, and in the public housing project, to target narcotics trade, violent crime, and gang-related activity.

Their findings suggest that surveillance has no effect on crime rates. There was no reduction in overall monthly crime rates within these areas, and though violent crime rates fell, the results were not statistically significant. Displacement effects were also not statistically insignificant, and surveillance did not increase arrest rates for misdemeanor "quality of life" infractions in either location. A pre/post matched analysis shows decreases in crime levels in both treatment and control areas, but smaller treatment reductions than control ones. The authors conclude that differences are statistically insignificant and indistinguishable from random fluctuation (Cameron et. al. 2008, 4).

2.2.4 Philadelphia, Pennsylvania

The City of Philadelphia constructed 18 cameras between July and November of 2006 in a variety of locations, residential and commercial, around the city. The Philadelphia Police Department proactively monitors feed from these cameras, and officers may also access real-time feed from their patrol cars. The system targets in particular public disorder crime types.

Ratcliffe and Taniguchi (2008) analyze the effect of these cameras on crime levels using a weighted displacement quotient approach that also measures displacement into adjacent areas but does not account for biases from seasonal trends. Their short analysis finds that four of the camera sites reduced "serious" crime (a combination of violent and property crimes) in the immediate target area and had a diffusion of benefits to adjacent streets, while four others had no local treatment effect.

2.3 Surveillance and the general equilibrium level of crime

There has been little variation in the theoretical debate over surveillance and its effects on criminal behavior in the past decade, and scholars continue to hold tenaciously to the dictates of rational choice theory. But if data-driven evaluations are often casting doubt on that hypothesis, then perhaps the current theoretical model, however intuitively compelling, is inadequate.

I present an alternative theory of the effect of camera surveillance based on the idea of strategic interaction between offenders and the police. This study is motivated by a theoretical wrinkle I have encountered in my interviews with law enforcement officials over the course of this research. Cameras cannot be treated as "extra cops" in any sense; they provide added information to police, yet cannot by themselves enforce the law. Still, no police department has unlimited resources, and with the added benefit of camera surveillance in certain sectors of the city, police may reallocate resources to other areas without that surveillance.

Game theory has yet to take hold in criminology as it has in economics and political science, and to the best of my knowledge only three articles have attempted to incorporate this strain of decision theory into questions of criminal behavior and decision making. Bueno de Mesquita and Cohen (1995) test the value of punishment strategies such as "three strikes" policies and welfare in deterring crime using noncooperative game theory, and Krebs, Costelloe, and Jenks (2003) analyze the effectiveness of drug control policies in a deterrence game between policymakers and narcotics smugglers and dealers. Tsebelis (1990) proposes a criminal-police interaction where, in equilibrium, the severity of the criminal penalty has no effect on offender behavior.[3]

I modify Tsebelis's model as a sequential-move game of complete information between police and offenders with the exogenous shock of camera surveillance installation.[4] The game consists of two players (the police as player 1, an offender as player 2) optimizing over two blocks of the city. The police allocate a constrained resource—on-the-ground police officers—over these two blocks according to a strategy $(\beta, 1-\beta)$. Offenders then view that distribution of officers and choose whether to offend in block 1 (O_1), offend in block 2 (O_2), or not to offend in either block (O_0). The factors of the game are as follows:

- **Police payoffs:** The goal of the police is to minimize crime.
- **Offender payoffs:** An offender has a benefit to crime of W_C—a personal value that is set exogenously. Offenders are drawn from a larger pool of potential offenders, and each individual holds a unique valuation of W_C that determines the "threshold to criminality" at which that individual, having

[3] Beyond simple offender behavior, game theory has also been incorporated into decisions involving co-offending (McCarthy, Hagan, and Cohen 1998); terrorist usage of weapons of mass destruction (Franck and Melese 2004); legal and illegal gun ownership (Correa 2005); sociopathic behavior (in Matthews 1997); the appeal to the right against self-incrimination (Schneider 2004); and the mafia (Smith and Varese 2001).

[4] I credit Gibbons (1997) for providing an introduction to the broader framework of dynamic Bayesian games and Professor Justin Fox at Yale University for his help in conceiving of and refining this model.

weighed the risks of breaking the law, will deem criminal action rational or irrational.

- **Risks of illegal activity:** The rational offender, according to Freeman (1999), commits a crime when:

$$(1 - p)W_C - (p)S > W_L$$

where W_L is the payoff from legitimate-market activity, S is the extent of punishment, and p is a baseline probability of arrest and conviction.

- **Effect of police:** Each incremental police officer affects the probability of arrest/conviction p by some value $\alpha > 0$.

- **Definition of parameters:** W_L, S, and p are set exogenously and uniformly for all individuals within the offender pool. The probability of arrest is greater than 0 ($0 < p < 1$) and offenders are distributed uniformly over the valuations of crime W_C, i.e. $W_C \sim U(0,1)$.[5]

- **Time horizon:** There are two "periods" of the game. The "pre" period occurs before camera installation, wherein neither block has a surveillance camera. Camera surveillance enters block 1 exogenously in the "post" period. This camera increases the probability of arrest/conviction by $0 < \delta < \alpha$.[6]

Pre-camera installation

THEOREM 1: In equilibrium, the optimal police allocation before surveillance installation will be (½, ½).

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[5] This implies that there is always some baseline level of risk involved in breaking the law.

[6] I attribute this possible increase to the increased probability of conviction with compelling video evidence. Note, though, that the surveillance camera is explicitly less "effective" in producing arrests and convictions than a police officer.

Proof of Theorem 1: Police will choose an allocation $(\beta, 1-\beta)$ so as to minimize crime. This occurs when the potential offender is indifferent between O_1 and O_2. Given a police allocation β, the offender's set of payoffs is:[7]

$$u_2(O_1) = \big(1-(p+\beta\alpha)\big)W_C - (p+\beta\alpha)S$$

$$u_2(O_2) = \big(1-(p+(1-\beta)\alpha)\big)W_C - (p+(1-\beta)\alpha)S$$

$$u_2(O_0) = W_L$$

The offender chooses among his or her strategies by weighing the riskiness of crime against his or her personal valuation of criminal activity. (S)he commits an offense in block 1 if:

$$W_{C,pre}^1 > \frac{W_L + (p+\beta\alpha)S}{1-(p+\beta\alpha)}$$

and an offense in block 2 if:

$$W_{C,pre}^2 > \frac{W_L + (p+(1-\beta)\alpha)S}{1-(p+(1-\beta)\alpha)}$$

This "threshold to criminality" is directly increasing to police allocation β in block 1, yet inversely decreasing to β in block 2. The police face a clear tradeoff: increasing resource allocation in one block will increase the criminal threshold there but decrease the threshold in the other block. Because offenders are distributed over valuations of W_C, a lower threshold in one block means that there is a greater proportion of the offender pool willing to commit a crime there.

Intuitively, it seems that police will thus minimize crime by setting W_C equal in both blocks. In this case, offenders are indifferent between the two blocks, and

[7] $0 < \alpha \leq \frac{1-p}{b}$.

any departure from that allocation will increase crime by lowering the threshold in one of the two blocks. Setting $W^1_{C,pre} = W^2_{C,pre}$ and solving for β:

$$\frac{W_L + (p + \beta\alpha)S}{1 - (p + \beta\alpha)} = \frac{W_L + (p + (1 - \beta)\alpha)S}{1 - (p + (1 - \beta)\alpha)}$$

and, through some algebraic manipulations,[8]

$$\beta^*_{pre} = \frac{1}{2} \tag{1}$$

In equilibrium, police minimize crime by choosing allocation strategy $S^*_{1,pre} = (1/2, 1/2)$.

Given this police distribution, only those individuals in the offender pool with a value of criminality of

$$W^*_{C,pre} > \frac{2W_L + 2pS + \alpha S}{2 - 2p - \alpha} \tag{2}$$

will commit a crime. Assuming offenders are uniformly distributed over W_C, the proportion of this pool willing to offend thus equals:[9]

$$\text{Offending population}_{pre} = 1 - \frac{2W_L + 2pS + \alpha S}{2 - 2p - \alpha} \tag{3}$$

Post-camera installation

THEOREM 2: Under surveillance, police in equilibrium will allocate $(\frac{\alpha-\delta}{2\alpha}, \frac{\alpha+\delta}{2\alpha})$. Police therefore redistribute resources away from the surveilled block.

Proof of Theorem 2: Surveillance enters as an exogenous shock to block 1 and increases the probability of arrest and conviction by some quantity $0 < \delta < \alpha$ through

[8] Appendix A presents the algebra behind these conclusions.

[9] This is a reason for why law enforcement is searching endlessly for new policing strategies. Technology (other than cameras) may increase the effectiveness of police α. Also, law enforcement may launch initiatives targeting specific crimes, which would increase the probability of arrest and conviction for certain offenses.

any of the myriad mechanisms listed in part 2.1.[10] This probability increase affects the offender's payoff function to offending in block 1 only:

$$u_2(O_1) = \big(1 - (p + \beta\alpha + \delta)\big)W_C - (p + \beta\alpha + \delta)S$$

$$u_2(O_2) = \big(1 - (p + (1 - \beta\alpha))\big)W_C - (p + (1 - \beta\alpha))S$$

$$u_2(O_0) = W_L$$

The offender again determines whether or not to commit an offense by determining the threshold at which criminality is a rational choice:

$$W_C^1 > \frac{W_L + (p + \beta\alpha + \delta)S}{1 - (p + \beta\alpha + \delta)}$$

$$W_C^2 > \frac{W_L + (p + (1 - \beta)\alpha)S}{1 - (p + (1 - \beta)\alpha)}$$

Through the same logic as in the pre-surveillance period, the police minimize crime by determining their allocation $(\beta, 1 - \beta)$ where $W_C^1 = W_C^2$:

$$\frac{W_L + (p + \beta\alpha + \delta)S}{1 - (p + \beta\alpha + \delta)} = \frac{W_L + (p + (1 - \beta)\alpha)S}{1 - (p + (1 - \beta)\alpha)}$$

Through a series of algebraic manipulations:

$$\beta_{post}^* = \frac{\alpha - \delta}{2\alpha} \quad (4)$$

The police therefore allocate resources away from the camera block by some "compensation factor" $\frac{\alpha-\delta}{\alpha}$. Note that, given $\alpha > 0$ and $\alpha > \delta > 0$, this factor is always less than 1, and so in equilibrium the police will always reduce the number of officers in the surveilled area, settling on an optimal allocation $(\frac{\alpha-\delta}{2\alpha}, \frac{\alpha+\delta}{2\alpha})$.

The optimal police allocation after surveillance leads to a corollary:

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[10] $0 < \alpha \leq \frac{1-p-\delta}{b}$.

Corollary 1: The change in crime levels will be uniform across the two blocks, i.e. there will no discernible local treatment effect of surveillance.

This corollary must be so as the equilibrium police allocation is determined by setting the criminal threshold equal across the two blocks. Offenders valuing W_C above this threshold will be indifferent between O_1 and O_2, and offenders with a valuation less than the threshold will not offend. Specifically, the offending population will value criminality above:

$$W^*_{C,post} > \frac{2W_L + 2pS + \alpha S + \delta S}{2 - 2p - \alpha - \delta} \tag{5}$$

These equilibrium changes due to surveillance suggest one final proposition: This change in police distribution as well as the effect of the incrementally higher risk from the camera *decreases the overall level of crime* by increasing the threshold to criminality by some value. This then decreases the proportion of the pool of potential offenders willing to commit a criminal act, based on the distribution of offenders over W_C.

THEOREM 3: The implementation of camera surveillance will always decrease the equilibrium level of crime from the pre-surveillance equilibrium level of crime.

Proof of Theorem 3: I compare the threshold of criminality in the post-camera period to the pre-camera period by comparing $W^*_{C,pre}$ and $W^*_{C,post}$. I subtract inequality (3) from inequality (5):

$$\Delta W_C = \frac{2W_L + 2pS + \alpha S + \delta S}{2 - 2p - \alpha - \delta} - \frac{2W_L + 2pS + \alpha S}{2 - 2p - \alpha}$$

This results in the change in the criminal threshold over the two periods:

$$\Delta W_C = \frac{2\delta(W_L + S)}{4p^2 + \alpha^2 + \delta(2p + \alpha - 2) + \alpha(4p - 4) - 8p + 4} \tag{6}$$

We can confirm that this change is always greater than 0 by setting up such an inequality and cross-multiplying:

$$\Delta W_C = 2\delta(W_L + S) > 0 \tag{7}$$

The implementation of surveillance in this framework always increases the value of W_C at which offending is rational. This increase will consequently decrease the proportion of the offending pool that is willing to commit an offense. This reduction in the offending population is illustrated in Figure 3.

This analysis signals two important departures from the predictions made by Rational Choice Theory and Situational Crime Prevention:

1) There will be ***no observable crime reduction benefit in surveillance-treated blocks*** relative to comparable control blocks if the police are efficiently reallocating their resources in response to the installation of surveillance.
2) Even if there is no observable local deterrent effect, police may still be ***minimizing overall crime*** if they redistribute their resources efficiently after camera installation.

3 Camera Surveillance in New City

This study analyzes the effects of surveillance in New City[11], a mid-size urban area in the U.S. with violent and property crime rates well above the national average but somewhat on par with the average across comparably-sized cities (Table 1).

[11] I have cloaked the name of the city in question to preserve the integrity of policing efforts and the surveillance program. The Police Department expressed concern that this study might jeopardize surveillance officers or equipment by revealing the locations of the cameras, thus inviting attacks. Descriptive characteristics of the city, however, are factual.

Demographically, the city is majority African-American with a large and growing community of Hispanics. The narcotics trade, particularly in heroin, in New City is robust because of the city's proximity to multiple transportation networks.

The surveillance program began in early 2006, just before a shake-up of the city's law enforcement apparatus. In 2007, the New City Police Department (NCPD) began significant reforms, tracking crime statistics more rigorously, seeking crime trends and patterns through mapping, re-prioritizing offenses and policing strategies, and increasing hiring of police recruits.[12] The city also purchased helicopters for police activity and formed a task force directed explicitly at gangs and narcotics, both with the intention of attacking the drug trade and organized gang activity at a higher level. This paper's empirical challenge is to disaggregate the effects of the surveillance initiative from other interventions occurring during the same period.

The NCPD surveillance initiative is particularly ripe for evaluation. Using a technical evaluation scheme proposed by Gill and Spriggs (2005), I characterize the context of the surveillance system as follows:

- **Scheme objectives.** Interestingly, the NCPD lists deterrence as the last of their professed goals of surveillance. More important objectives include detection of crimes already in progress, faster and more efficient emergency services response, and more successful criminal prosecutions and investigations.

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[12] For instance, the Department now places less emphasis on policing activity towards low-level drug busts than it once did.

- **Management.** The NCPD and the Mayor's Office initiated the surveillance program, and the NCPD has retained control of its management ever since. Funding comes from community foundations as well as federal, state, and local grants. The Department, along with the Mayor's Office, determines camera locations, positioning, and technical specifications (construction was contracted to an outside vendor).
- **Density.** By my own approximation, the 105 cameras cover about 20% of the city, yet this estimate is likely a charitable one. Density is higher in some areas, such as commercial thoroughfares and dense residential areas.[13]
- **Camera coverage and positioning.** Except where obstructed by foliage or buildings, all cameras in the system have 360-degree views and at least a mile-long line of sight (actual viewshed is site dependent). The cameras are designed to obscure their direction of focus from individuals under surveillance. As discussed earlier, this allows for a continued impression of surveillance—and possibly a uniform deterrent capacity—even as operators pan to different locations. The first eight cameras were constructed on rooftops and are not visible from the street, but all others are conspicuously located atop traffic or light poles.
- **Technical characteristics.** New City fully owns and operates the wireless network on which the cameras operate—in contrast to the practice in such areas as New York City of buying wireless space from an existing provider. This wireless network also allows officers to access real-time surveillance

[13] This estimate is based on the proportion of the inhabited areas of the city falling within a 500' buffer from the cameras.

feed from laptops mounted in their patrol cars. Cameras have color, all-weather, and low-lighting functionality, and 20 are fitted with bullet-resistant encasing.[14]

- **Operation of the control room.** Two to three supervisors monitor the cameras for 16 hours each day, seven days/week. The cameras continue to record during the eight "unmonitored" hours, which run from 3:30 a.m.-11:30 a.m., when the city's bars and clubs close. Offenses witnessed by camera operators enter the police CAD log, a queue of reported incidents prioritized by crime type and severity. Most surveillance room operators have worked previously in gang- and narcotics-related police work in the city, and so are attuned to crime patterns and behavior. The Department intends to expand monitoring to 24 hours/day once the city's budget allows.

The above characteristics distinguish the system from others in operation in the U.S. in two important ways: First, the system is actively monitored (San Francisco, as referenced earlier, only passively records for evidence in trial) and constitutes a tool for proactive policing and deterrence not common in other municipalities. Second, the surveillance system is an integral part of other police work in the city, centralized in and directed by the same body responsible for all other law enforcement activity. The NCPD system would thus seem to be a model offering the greatest possible effectiveness.

[14] The city abandoned the bullet-resistant enclosure in later phases because the casings slow camera movements.

3.1 Data Description

3.1 Data Description

This study runs from the first quarter of 2005 through the first quarter of 2009. The data analyzed in this study are from the New City Police Department and constitute reported Part I violent and property crimes occurring within city limits during this 17-quarter period.[15] Criminal events were geocoded to ensure a precise and comprehensive understanding of the distribution and movement of crime across New City. The units of observation are 500' x 500' cells ("blocks").[16] There are a total of 2,957 such blocks through the city, yet excluding those that never see an offense during the four-year period reduces the total number of units to 1,707.

New City's 105 cameras were constructed over four phases.[17] The NCPD recorded neither the dates nor the process of camera construction. However, using billing dates from the contracted construction firm, model and location information from the surveillance program at the central surveillance center, and the recollections of one of the central architects of the plan in the NCPD, I have recreated the timing and locations of the surveillance roll-out. The NCPD implemented a different model of camera with each phase, and I have matched these different phases to dates provided by the wireless construction firm and the NCPD

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[15] Data was obtained on the following Part I offenses as defined by the FBI's Uniform Crime Reporting system: aggravated assault, criminal homicide, motor vehicle theft, burglary, robbery, and larceny theft.

[16] I use this cell size as the "target area" because it follows exactly the grid that the LCPD used to analyze crime distribution across the city for their initial attempt at camera placement. Other studies have looked at a smaller target range, but bear in mind that 500 feet is roughly equivalent to two North-South blocks in New York City (Bridges 1811).

[17] The city has actually constructed 109 cameras, but I exclude four locations from this analysis. Three cameras have been "downed" by vehicle accidents, and the fourth was operationalized as recently as February 2009.

official. According to the resulting confluence of these sources of information, each phase of construction appears to have occurred within a three-month window. Phase 1 consists of nine cameras installed in quarter 1 of 2006; Phase 2, of 25 cameras in quarter 2 of 2007; Phase 3, of 20 cameras in quarter 1 of 2008; and Phase 4, of 55 cameras in quarter 3 of 2008. Treatment data may not be as granular and exact as it could have been, but I am confident in the validity of the data within this three-month spread.

Offenses are collapsed to quarterly data. The resulting panel data present the number of offenses in a given block over the 17 quarters of the study. Treatment changes from 0 to 1 in the quarter of installation. Table 2 presents summary statistics for the different crime types and the treatment blocks. Note that column (3) signifies the total number of offenses by crime type occurring in the sample.

Selection issues

Treatment is not exogenous to the distribution of crime, nor is it determined by any observable factor. It also is not random. The NCPD initially recommended placing cameras in the highest-crime areas of the city. To that end, the Department superimposed a 500' x 500' grid on the city and ranked each cell (block) by the total number of offenses occurring there from quarter 1 of 2005 to quarter 1 of 2007. I replicated this grid and the crime index with geocoding but found that the ranking did not determine final camera placements.

According to authorities familiar with the program's design, political and budgetary factors also influenced the final location choices. For instance, the city constructed a camera in the courtyard of a senior housing project with moderate levels of crime. This placement was not intended to deter offenses, but to displace the project's thriving drug trade out from the courtyard.

4 Empirical Strategy

This study proposes to estimate the effect of camera surveillance on crime rates. The best-case situation in which to examine this effect is random assignment of surveillance; as the number of observations approaches infinity, the untreated group will theoretically be indistinguishable from the treated group, on average. Any change in the treated group relative to the untreated group would be subject to two interpretations—random fluke, or a causal effect of camera surveillance—but as the sample size grew, a causal effect would be more probable.

Unfortunately, the world of law enforcement is not always so kind to researchers, and surveillance in New City was not randomly assigned. Instead, the surveillance system offers a nonequivalent group design—treated blocks have higher pre-surveillance crime on average than non-treated blocks in the city, yet not in an entirely systematic fashion. This differential selection poses an obvious threat to the internal validity of any basic pre-test, post-test analysis. But it is possible to analyze the surveillance system instead as a "quasi-experiment" by searching for a fortuitous source of near-random variation in selection.

A note on dependent outcome selection

I elect to narrow my dependent variables to aggravated assaults and auto thefts in order to ensure that the analysis is not biased by "bad" data. Reported offenses often suffer from underreporting, whether for political reasons or because crimes simply are not reported consistently. I focus on aggravated assaults and auto thefts, as both are reliably reported crimes. Aggravated assaults will be reported either through a direct report to police or a victim's hospital visit.[18] Auto thefts will also be reported reliably for purposes of insurance collection. Further, auto thefts nearly always take place out-of-doors, i.e. within view of a potential camera.

4.1 Nonparametric difference-in-differences estimation

I employ nearest-neighbor matching, with a so-called "caliper" standard, to construct a control group out of this study's nonequivalent group design. This matching strategy compares treatment and control units with approximately identical background attributes to create the appearance of controlling for initial selection differences. The treatment effect is then estimated from the posttest difference between matched pairs.

I use this strategy conscientiously as matching often has a bias to the positive (Arceneaux, Gerber, and Green 2006).[19] Recall that control blocks are immediately adjacent to treatment blocks, and so control blocks are likely to see a crime increase due to spillover effects as offenders move out of surveillance blocks. If surveillance has a local deterrent effect, this analysis will tend to show a greater reduction in crime in the treatment block relative to control because the treatment blocks' decline is causally linked to the control blocks' increase. The causal effect—derived from the difference between the two changes—will tend to be overstated.

Blocks are matched according to a pretest score based on prior offenses. Each block containing a camera ("target" or "treatment" block) is surrounded by eight

[18] Aggravated assault constitutes an attack that intends to inflict severe bodily injury, such as a non-fatal shooting, and is usually carried out with a deadly weapon (*Uniform Crime Reporting Handbook*).

[19] The matching method also removes biases in post- period comparisons between treatment and control groups resulting either from permanent differences between the two groups (differential selection) or from time trends.

adjacent blocks ("adjacent"). Together, these nine blocks form a "cluster".[20] Within each cluster, I use geocoding software to search for an adjacent block sharing a similar total number of offenses in the four quarters prior to camera installation. The caliper standard is +/-2 offenses. In cases of multiple matches, adjacent blocks are aggregated into a single control block. Any unmatched treatment observations are not included in the estimation.

A difference-in-differences (DD) estimation compares the crime outcomes of the groups over time. The crime outcomes of the two groups are observed over two time periods, pre- installation and post-installation. The treatment group is exposed to surveillance throughout the post- period. The estimation compares the proportion of blocks within each group that sees a reduction, increase, or no change in crime from the post- period to the pre- period. I repeat the estimation over Phases 1, 2, 3, and 4 (defined in Section 3.1).

This nonparametric DD estimation can be stated formally as:

$$\text{Crime Reduction} = \frac{i \text{ where } \left(\sum_{t\in post} y_T - \sum_{t\in pre} y_T\right) < 0}{n} - \frac{i \text{ where } \left(\sum_{t\in post} y_C - \sum_{t\in pre} y_C\right) < 0}{n}$$

$$\text{Crime Constant} = \frac{i \text{ where } \left(\sum_{t\in post} y_T - \sum_{t\in pre} y_T\right) = 0}{n} - \frac{i \text{ where } \left(\sum_{t\in post} y_C - \sum_{t\in pre} y_C\right) = 0}{n}$$

$$\text{Crime Increase} = \frac{i \text{ where } \left(\sum_{t\in post} y_T - \sum_{t\in pre} y_T\right) > 0}{n} - \frac{i \text{ where } \left(\sum_{t\in post} y_C - \sum_{t\in pre} y_C\right) > 0}{n}$$

where $post$ is the four quarters after camera installation, pre is the four quarters prior to camera installation, y_T is the number of offenses occurring in treatment

[20] Because some cameras are positioned closely together, certain blocks may fall in multiple clusters. I code these blocks as part of the earliest constructed cluster.

group i in quarter t, y_C is the number of offenses occurring in control group i in quarter t, and n is the total number of matched observations in a given phase.[21]

4.2 Ordered probit estimation

The second estimation strategy uses an ordered probit model to estimate the effect of surveillance on the probability of a crime decrease, increase, or constancy. Crime reduction is coded as -1, constancy as 0, and increase as 1. Consider that we may estimate the distribution of blocks over this (-1, 0, 1) index according to the equation:

$$y^* = \alpha + \beta(\text{Treat}) + \varepsilon$$

y_i is the outcome of increase, decrease, or constancy in block i. We observe $y = -1$ where $y^* \leq \delta_1$, $y = 0$ where $\delta_1 \leq y^* \leq \delta_2$, and $y = 1$ where $y^* \geq \delta_3$ (Kennedy 2003, 278). These three δ "thresholds" are estimated by a maximum likelihood estimator, where the ordered probit assumes that ε is normally distributed. The log-likelihood function for each observation i is (Wooldridge 2002, 505):

$$\ell_i(\boldsymbol{\alpha}, \boldsymbol{\beta}) = 1[y_i = -1] \log[\Phi(\alpha_1 - x_i\beta)] + 1[y_i = 0] \log[\Phi(\alpha_2 - x_i\beta) - \Phi(\alpha_1 - x_i\beta)] + 1[y_i = 1]\,[1 - \log\Phi(\alpha_3 - x_i\beta)]$$

This estimation approach allows us to estimate a possible treatment effect on the probability of a given block seeing a crime reduction, increase, or constancy over the two time periods by calculating differences in predicted probabilities between control and treatment groups.

[21] Phase 4 cameras were constructed in quarter 3 of 2008. The follow-up time period for that phase, then, is only two quarters. This does not bias the estimates in and of themselves, as seasonal variation would be constant over treatment and control.

5 Results

The results of the matching analysis and ordered probit estimation suggest that there is no effect of surveillance on crime levels. Table 3 presents the results of the matched, nonparametric difference-in-differences method of specification 1. In three out of seven cases (Phase 2 and Phase 3 aggravated assault, Phase 3 auto theft), a greater proportion of treatment blocks than control blocks experience a reduction in crime over the two-year period. But in Phase 4, for instance, treatment blocks see more of a crime increase than do control blocks. Averaging across the phases, 51.1% of the control group sees a crime decrease, 10.9% constancy, and 38.0% an increase. The treatment group, in contrast, sees a crime reduction in 40.2% of the blocks, no change in 34.8%, and an increase in 25.0%.

In interpreting these results, bear in mind that this matching model is biased in favor of finding an effect; if surveillance did reduce crimes locally, we should see exaggerated reductions in the treatment group relative to the control group. But this specification finds no effect across all four phases in spite of the model's explicit tendency to overstate a causal effect. A Wilcoxon rank-sum test confirms this finding: In none of the eight cases can we reject the null hypothesis that the two groups, treatment and control, are drawn from the same population. Differences in median changes between the two groups—i.e. the treatment effect—are not significant across all crime and phase sub-groups.

The results of the ordered probit estimation corroborate the matching analysis (Table 4): Surveillance cameras have no effect on levels of aggravated assaults or auto thefts. Though there appears to be a slight crime-reduction effect of treatment on aggravated assaults, the coefficient on treatment is significant for neither aggravated assaults nor auto thefts. We thus fail to reject the null that surveillance has no effect on crime levels. Table 5 presents the predicted probabilities—the δ thresholds in part 4.2—resulting from the ordered probit estimates. Through all aggravated assault sub-categories, there is no difference in predicted probabilities of crime increase, decrease, or constancy between control and treatment groups. The groups do see some disparity in predicted probabilities for auto thefts, yet the differences are neither significant (as the ordered probit estimation suggests) nor appreciable.

These empirical findings have important implications for the theoretical validity of my proposed police-offender model in part 2.3. Overall, this analysis finds that nearly half of the matched sample sees a reduction in crime after the installation of surveillance (45.6%). This sizable decline suggests a benefit of surveillance treatment across both districts that is not manifesting as a localized treatment effect. This finding accords with the conclusion of my proposed model—that police, facing resource constraints, will allocate away from a treated camera district, allowing crime levels to re-equilibrate uniformly across treated and untreated blocks, yet minimizing crime at a lower level than in the equilibrium without surveillance. The absence of a treatment-block-only effect of surveillance therefore does not imply that the cameras have no effect, but rather that police may be efficiently reallocating their resources and driving crime down uniformly over a larger geographical area.

5.1 Threats to inference

I address three possible threats to inference in this analysis:

1) **Regression to the mean.** Regression to the mean is the tendency for any stochastic process to revert to a long-run average over time. This tendency is stronger the farther away the first measurement is from the mean. It is possible that cameras were selected into locations that were experiencing high but essentially random spikes in crime. As time went on, crime in these blocks would regress to the mean, though we would misattribute this decline to a treatment effect of surveillance. The existence of mean regression would bias the study in favor of finding an effect. The empirical results in this analysis point to no treatment effect, however; mean reversion is likely not a significant threat to inference in this study.

2) **Displacement effects.** The bias from a spillover of crime from treatment to control blocks is already accounted for in the matching design. If anything, spillover effects would further bias the analysis in favor of finding an effect, as there would be an exaggerated difference between crime-increasing control blocks and crime-decreasing treatment blocks.

3) **Higher rates of detection.** A spike in reported crimes in the treatment blocks would bias this study against finding an effect. Camera surveillance may increase reporting of crimes in treatment blocks as actively monitored cameras detect offenses that would otherwise have never been reported. Crime rates would appear to be constant or increasing in treatment blocks, while in reality those rates would be a more accurate reflection of crime levels across the city. Given that the analysis has found no effect, higher rates of detection may be masking a true local treatment effect.

6 Discussion and Conclusion

This analysis has found no local deterrent effect of surveillance through a matching analysis and an ordered probit estimation that examined changes in levels of crime within matched treatment and control blocks. However, crime appears to have decline across the sample as a whole in the post-treatment period, an empirical result that accords with the predictions of my proposed model in section 2.3. These findings raise questions for the policy world while also calling clearly for further research.

6.1 Policy implications

Although this study has shown that surveillance may reduce overall crime without manifesting a local treatment effect, the future of surveillance as a widespread law enforcement tool in the U.S. is far from guaranteed. Surveillance still presents a principled, if not legal, challenge to fourth Amendment privacy protections. However, such arguments have not swayed U.S. courts against the proliferation of surveillance. No federal statute or court case has yet directly limited the operation of silent camera surveillance programs such as the one studied in New City, and most related case law would suggest that the camera system is entirely constitutional.

Federal statutes since the late 1960s have constrained the legal scope of electronic surveillance, yet these statutes, including Title III of the Omnibus Crime Control and Safe Streets Act of 1968 and Title I of the Electronic Communications Act of 1986, address only surveillance that captures audio information. Within this context, courts have consistently ruled that video surveillance that does not intercept audio signals does not fall under the rule of either statute (Nieto 1997, 4-6).

Courts have systematically deemed silent video surveillance to be consistent with the two-part privacy test established by *Katz v. U.S.* (1967): Privacy interests exist where individuals hold a reasonable, if subjective, expectation of privacy, and where society objectively recognizes the merit of that interest. Within this context, *Katz* holds that, “What a person knowingly exposes to the public, even in his own home or office, is not a subject of Fourth Amendment protection” (*Katz v. U.S.* 1967). One year after *Katz*, *Harris v. U.S.* (1969) cemented the “plain view doctrine” for lawful seizure of evidence that has since extended to video surveillance evidence as well. The Ninth Circuit Court of Appeals, a court with a history of pro-civil rights rulings, has ruled that “Video surveillance does not in itself violate a reasonable expectation of privacy […] the police may record what they normally may view with the naked eye” (*U.S. v. Taketa* 1991). And in 1993, the Ninth Circuit again argued that video surveillance evidence prevented in the court was constitutional, as “Everything that was captured by the camera could just as easily have been seen by a person hiding in the trees where the camera was located” (*United States v. Sherman* 1993). So long as surveillance is not targeted at private environments or other areas in which warrantless police presence would be illegal, and so long as it does not capture that which a police officer could not reasonably see, then surveillance does not constitute an unreasonable search under the Fourth Amendment (Blitz 2003).

Privacy rights advocacy groups have worked with the architects of several surveillance systems in the U.S. to help allay citizen concerns about law enforcement surveillance as the herald of a “Big Brother” society. The ACLU, for instance, negotiated with San Francisco surveillance architects to disable the cameras during political demonstrations (King et. al. 2008, 16). New City has also made concessions to civil liberties groups: Cameras record continuously for 30 days, and then begin to record over that film on day 31. All footage is thus eventually destroyed unless an incident has occurred on film. The surveillance system also employs digital masking technology to block visibility into or recording of all private areas, such as apartments or private offices. Access to recorded, stored incidents is also limited by a stringent application process within the city's criminal justice system.

Beyond simple crime reduction, however, there are other benefits to surveillance technology. Some studies have found a reduced level of fear of crime in areas with visible CCTV surveillance, perhaps aiding in economic growth due to an enhanced feeling of security. Surveillance operators also work with emergency medical services when they witness a crime in progress. And in a realm completely divorced from criminology, the coincidental expansion of a wireless network with the surveillance program may enhance other police functions. For instance, the NCPD plans to "loan" wireless network access to a nearby hospital for "mobile mammographies" throughout the city. For surveillance to be accepted on a wider scale across the U.S., cities would be wise to publicize some of the tangential benefits from the construction of such a system.

6.2 Conclusion

These results do not necessarily challenge previous studies' findings on the effectiveness of surveillance programs, particularly the conclusions of those evaluations being conducted in the U.S., but they do dispute the initial expectations of this surveillance literature. Rational Choice Theory, which posits that offenders under surveillance will choose not to commit a crime given a higher probability of arrest and conviction, predicts that surveillance will cause a localized decline in crime. However, the empirical results of this paper do not match that hypothesis.

Surveillance did not reduce crime in the target area—and while it is possible that offenders in New City are not entirely aware of the surveillance cameras, for instance, it is also plausible that police are optimizing their allocation of constrained resources given the new surveillance paradigm. My proposed model in section 2.3 suggests that surveillance will reduce the overall level of crime yet will distribute that decrease evenly over camera and non-camera blocks—a previously unexplored proposition in this field.

From a scholarly standpoint, these results call for research in two key areas. First, researchers and cities alike should undertake experimental research on the effect of surveillance on crime rates. The experimental approach offers a distinct advantage over the quasi-experimental methodologies used in this paper, as randomization would allow researchers to disentangle the underlying causal mechanism from other factors determining outcomes in treatment and control groups. Such research, however, may currently be unpopular with financially-strapped municipal governments who are, understandably, reluctant to construct cameras in areas of their cities where crime is not a problem. Yet, such a randomized system would be both unprecedented and invaluable in unearthing the true causal effect of camera surveillance.

Second, the theoretical model proposed in this paper calls for expanded research on general equilibrium effects in criminology. The popularity of Rational Choice Theory has perhaps made researchers focus myopically on the offender alone.

Surveillance certainly should influence the decision making calculus of an offender in view of the camera, but the police, as another rational actor, have an opportunity to react to that altered calculus. If offenders are geographically mobile, they may simply choose to offend elsewhere, and if police correctly anticipate that movement away from the camera districts, their rational response is to reallocate resources to those areas. The police response thus becomes a careful balance of leveraging the increased riskiness of criminal activity from the surveillance cameras while reallocating some resources away from those surveilled blocks.

In this way, surveillance changes the conditions of an entire city, not just the blocks in which cameras are constructed. Future studies must look not only at the precise treatment area and the offender's decision making calculus in that location, but also at police responses to the changed circumstances on a city-wide level. On this broader plane, individuals' rational adaptations to surveillance may result in a new general equilibrium level of crime across the city. This equilibrium analysis should also extend beyond surveillance to further policing tactics, state and federal law enforcement policies, and other unsolved questions in criminology.

In the end, this study's contributions were to add to the small yet growing evaluation literature on surveillance in the United States and to extend the current theoretical framework to not only criminal, but also police responses to surveillance. The paper only begins the process, however, of evaluating more rigorously the implications of camera surveillance for America's cities.

7 Tables and Figures

Table 1: Crime rates, 2006 (per 100,000 population)

	New City	Mid-sized cities	Nationally
Violent Crime	1,011	995	589
Property Crime	4,078	5,214	3,991

Source: FBI Uniform Crime Reports (2006)

Table 2: Data description of variables used in regression analyses

	Mean	Standard Deviation	*n*
Total Crime	1.711	1.978	46,720
Aggravated assault	.127	.400	3,463
Auto theft	.702	1.042	19,140
Burglary	.211	.537	5,743
Homicide	.014	.124	374
Robbery	.189	.481	5,156
Theft	.471	1.043	12,844
Blocks			27,312
Treatment blocks			437

Table 3: Proportion of districts seeing increase, decrease, or no change in crime after surveillance installation. Matching based on aggravated assault or auto theft offenses in the one year prior to installation, +/- 2 offenses.

	Phase 1			Phase 2			Phase 3			Phase 4		
Aggravated Assault												
	Control (n = 8)	Treatment (n = 8)	Difference	Control (n = 25)	Treatment (n = 25)	Difference	Control (n = 16)	Treatment (n = 16)	Difference	Control (n = 43)	Treatment (n = 43)	Difference
Crime decrease	37.5%	37.5%	0	24.0%	28.0%	**+4**	25.0%	31.2%	**+6.2**	79.1%	51.2%	-27.9
No change	12.5%	50.0%	+37.5	16.0%	28.0%	+12	6.3%	43.8%	+37.5	9.3%	32.6%	+23.3
Crime increase	50.0%	12.5%	-37.5	60.0%	44.0%	-16	77.9%	68.7%	-9.2	11.6%	16.2%	+4.6
Rank-sum test		$p = 1$			$p > 0.5$			$p > 0.5$			$p > 0.5$	
Auto Theft												
	Phase 1			Phase 2			Phase 3			Phase 4		
	Control (n = 8)	Treatment (n = 8)	Difference	Control (n = 25)	Treatment (n =25)	Difference	Control (n = 16)	Treatment (n = 16)	Difference	Control (n = 45)	Treatment (n = 45)	Difference
Crime decrease	37.5%	25.0%	-12.5	52.0%	48.0%	-4	50.0%	56.3%	**+6.3**	97.8%	75.6%	-22.2
No change	0.0%	37.5%	+37.5	4.0%	36.0%	+32	12.5%	18.7%	+6.2	2.2%	4.4%	+2.2
Crime increase	62.5%	37.5%	-25	44.0%	16.0%	-28	37.5%	25.0%	-12.5	0.0%	20.0%	+20
Rank-sum test		$p > 0.5$			$p > 0.5$			$p > 0.5$			$p > 0.5$	

Note: "Difference" column indicates difference in percentage points between treatment and control. Rank-sum estimation a Wilcoxon rank-sum test.

Table 4: Effect of camera installation on aggravated assaults and auto theft—Ordered probit estimation

	Aggravated Assault (n = 184)	Auto Theft (n = 188)
Installation of Camera	-.002 (.175)	.226 (.194)
Phase 2 (dummy)	.436 (.327)	-.488 (.337)
Phase 3 (dummy)	.333 (.348)	-.512 (.337)
Phase 4 (dummy)	-.649** (.312)	-1.500** (.337)
Log-likelihood	-178.59	-143.00

Note: Ordered probit weighted by frequency of blocks in each group.
Standard error in parentheses.
**, * indicate statistical significance at the 5% and 10% level, respectively.

Table 5: Effect of surveillance treatment on predicted probabilities of crime decrease, constancy, or increase outcomes, by phase

Aggravated Assault								
	Phase 1		Phase 2		Phase 3		Phase 4	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
Pr(Crime decrease)	.400	.401	.245	.246	.279	.279	.654	.654
Pr(No change)	.261	.261	.264	.264	.254	.254	.202	.203
Pr(Crime increase)	.338	.339	.508	.508	.467	.467	.143	.144
Auto Theft								
	Phase 1		Phase 2		Phase 3		Phase 4	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
Pr(Crime decrease)	.297	.379	.482	.572	.491	.581	.833	.883
Pr(No change)	.144	.152	.142	.151	.141	.150	.059	.079
Pr(Crime increase)	.469	.559	.286	.367	.278	.358	.057	.088

Predicted probabilities generated from aggravated assault and auto theft ordered probit estimates (Table 4).

Fig. 1: Violent crime in the US, 1988-2007

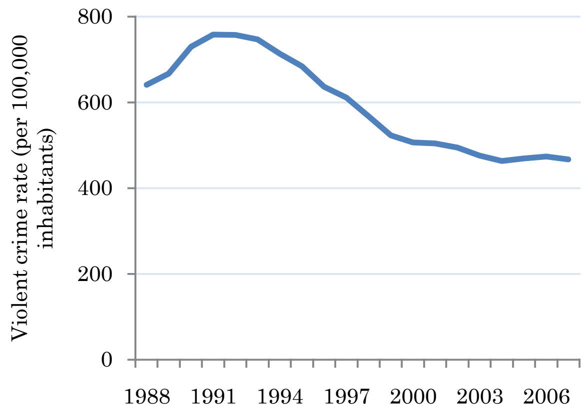
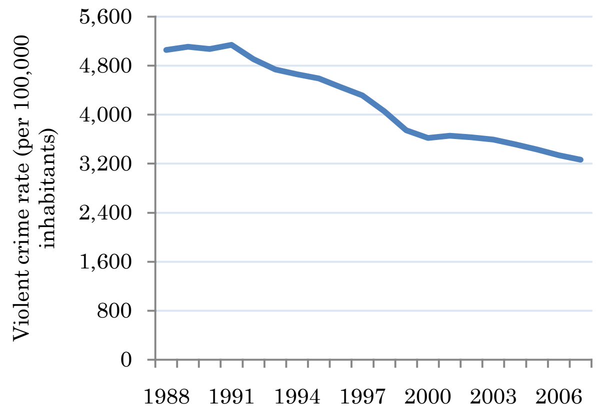
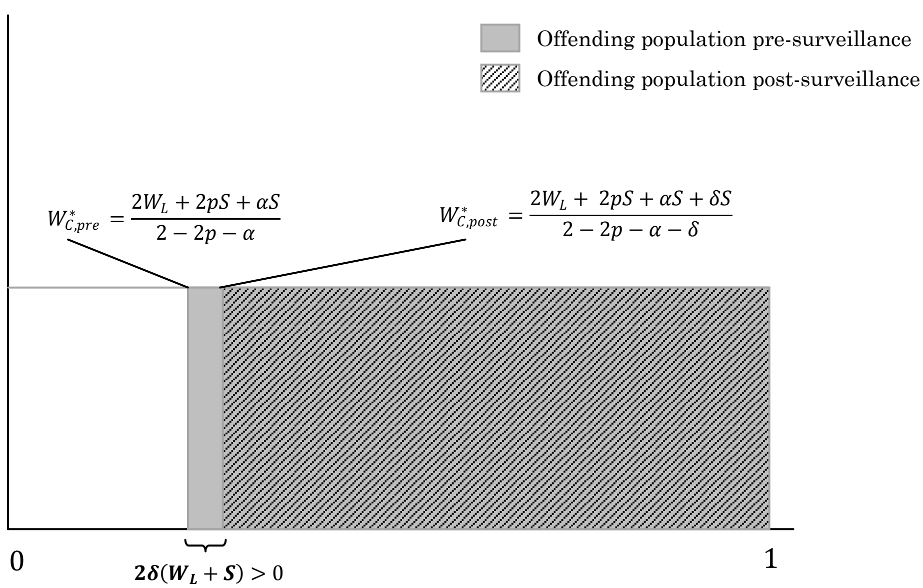


Fig. 2: Property crime in the US, 1988-2007



Source: Crime in the U.S. 2007, FBI

Fig. 3: Declines in the offending population from surveillance installation



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8 References

Arceneaux, Kevin, Alan S. Gerber, and Donald P. Green. 2006. “Comparing Experimental and Matching Methods Using a Large-Scale Voter Mobilization Experiment.” *Political Analysis* 14(1): 37-62.

Becker, Gary. “Crime and Punishment: An Economic Approach.” *The Journal of Political Economy* 76(2): 169-217.

Blitz, Marc Jonathan. 2004. “Video Surveillance and the Constitution of Public Space: Fitting the Fourth Amendment to a World that Tracks Image and Identity.” *Texas Law Review* 82(6): 1350-1479.

“Britain is ‘surveillance society’.” 2 November 2006. *BBCNews.com*. < http://news.bbc.co.uk/1/hi/uk/6108496.stm>. (24 April 2009).

Bueno de Mesquita, Bruce, and Lawrence E. Cohen. 1995. “Self-Interest, Equity, and Crime Control: A Game-Theoretic Analysis of Criminal Decision Making.” *Criminology* 33(4): 483-518.

Cameron, Aundreia, Elke Kolodinski, Heather May, and Nicholas Williams. 2008. “Measuring the Effects of Video Surveillance on Crime in Los Angeles.” California Research Bureau. <http://www.library.ca.gov/crb/08/08-007.pdf>. (25 April 2009).

Clarke, Ronald V. 1995. “Situational Crime Prevention.” *Crime and Justice* 19: 91-150.

Cornish, Derek B., and Ronald V. Clarke. 1986. “Introduction by the Editors.” In *The Reasoning Criminal*, eds. D. Cornish and R. Clarke. New York: Springer-Verlag. Out of print. Accessed < http://www.popcenter.org/library/reading/?p=reasoning> (February 3, 2009).

Freeman, Richard B. 1999. “The Economics of Crime.” In *Handbook of Labor Economics* 3, eds. O. Ashenfelter and D. Card. Elsevier: 3529-3571.

Gibbons, Robert. 1997. “An Introduction to Applicable Game Theory.” *The Journal of Economic Perspectives* 11(1): 127-149.

Gill, Martin, and Angela Spriggs. 2005. “Assessing the Impact of CCTV.” Home Office Research Study 292 (February).
< http://www.homeoffice.gov.uk/rds/pdfs05/hors292.pdf>. (26 April 2009).

Glazer, Sarah. 1997. “Declining Crime Rates: Does Better Policing Account for the Reduction?” *CQ Researcher* 7(13).

Harris v. United States, 536 U.S. 545 (2002).

Johnson, Alex. 2008. "Smile! More and more, you're on camera." *MSNBC.com*. 25 June 2008. <http://www.msnbc.msn.com/id/25355673/>. (15 March 2009).

Katz v. United States, 389 U.S. 347 (1967).

Kennedy, Peter. 2003. *A Guide to Econometrics*. Cambridge: MIT Press.

King, Jennifer, Deirdre K. Mulligan, and Stephen Raphael. 2008. *CITRIS Report: The San Francisco Community Safety Program*. Berkeley: University of California, Berkeley, Center for Information Technology Research in the Interest of Society.

Krebs, Christopher P., Michael Costelloe, and David Jenks. 2003. "Drug Control Policy and Smuggling Innovation: A Game-Theoretic Analysis." *Journal of Drug Issues* 33(1): 133-160.

Langan, Patrick A. 2006. "Crime and Punishment in the United States, 1981-1999." *Crime and Justice* 33: 123-47.

McCahill, Michael and Clive Norris. 2002. "CCTV in London." Working Paper No. 6, Urban Eye RTD-Project. <http://www.urbaneye.net/results/ue_wp6.pdf>. (20 April 2009).

Nestel, Thomas J. 2006. "Using Surveillance Camera Systems to Monitor Public Domains: Can Abuse Be Prevented?" M.A. Thesis. Naval Postgraduate School.

Nieto, Marcus. 1997. "Public Surveillance: Is it an Effective Crime Prevention Tool?" Sacramento, California: California Research Bureau, California State Library.

Pawson, Ray and Nick Tilley. 1997. *Realistic Evaluation*. SAGE Publications.

Ratcliffe, Jerry. 2006. "Video Surveillance of Public Places." U.S. Department of Justice, Community Oriented Policing Guides. <http://www.cops.usdoj.gov/files/RIC/Publications/e02061006.pdf>. (1 April 2009).

Ratcliffe, Jerry and Travis Taniguchi. 2008. "CCTV Camera Evaluation: The crime reduction effects of public CCTV cameras in the City of Philadelphia, PA installed during 2006." Temple University, Department of Criminal Justice. <http://www.temple.edu/cj/misc/PhilaCCTV.pdf>. (18 April 2009).

Sheridan, Mary Beth. 2008. "D.C. Forging Surveillance Network." *The Washington Post*. A1. 1 May 2008.

Spielman, Fran. 2006. "Daley: By 2016, cameras on 'almost every block'." *Chicago Sun-Times*. 12 October 2006.

Tsebelis, George. 1990. "Penalty has no Impact on Crime: A Game-Theoretic Analysis." *Rationality and Society* 2(3): 255-286.

United States v. Taketa, 923 F. 2d 665 (1991).

United States v. Sherman, 990 F. 2d 1265 (1993).

U.S. Department of Justice. Federal Bureau of Investigation. 2004. *Uniform Crime Reporting Handbook.* Washington, D.C.: U.S. Department of Justice.

U.S. Department of Justice, Federal Bureau of Investigation. 2007. *Crime in the United States, 2006.* <http://www.fbi.gov/ucr/06cius.htm>. (10 April 2009).

U.S. Department of Justice, Federal Bureau of Investigation. 2008. *Crime in the United States, 2007.* <http://www.fbi.gov/ucr/07cius.htm>. (10 April 2009).

"Who's Watching? Video Camera Surveillance in New York City and the Need for Public Oversight." The New York Civil Liberties Union. Fall 2006. <http://www.nyclu.org/pdfs/surveillance_cams_report_121306.pdf>. (20 April 2009).

Wooldridge, Jeffrey M. 2002. *Econometric Analysis of Cross Section and Panel Data.* Cambridge: MIT Press. Foucault, Michel. 1977. *Discipline and Punish: The Birth of the Prison.* New York: Pantheon Books.

9 Appendices

9.1 Appendix A: Proof of theoretical model, section 2.3

Proof of equilibrium police allocation pre-surveillance (Equation 1):

1) $W_{C,pre}^{1} = W_{C,pre}^{2}$

2) $\frac{W_L + (p+\beta\alpha)S}{1-p-\beta\alpha} = \frac{W_L + (p+(1-\beta)\alpha)S}{1-p-(1-\beta)\alpha}$

3) $W_L - pW_L - \alpha W_L + \beta\alpha W_L + pS - p^2 S - p\alpha S + p\beta\alpha S + \beta\alpha S - \beta\alpha p S - \beta\alpha^2 S + \beta^2 \alpha^2 S = W_L - pW_L - \beta\alpha W_L + pS - p^2 S - \beta\alpha p S + \alpha S - \alpha p S - \beta\alpha^2 S - \beta\alpha S + \beta\alpha p S + \beta^2 \alpha^2 S$

4) $-\alpha W_L + \beta\alpha W_L + \beta\alpha S = -\beta\alpha W_L + \alpha S - \beta\alpha S$

5) $2\beta(\alpha W_L + \alpha S) = \alpha W_L + \alpha S$

6) $\boldsymbol{\beta^* = 1/2}$

Proof of equil. criminality threshold pre-surveillance (Equation 2):

1) $W_C^* = \frac{W_L+(p+\beta\alpha)S}{1-p-\beta\alpha}$

2) $W_C^* = \frac{W_L+\left(p+\frac{\alpha}{2}\right)S}{1-p-\frac{\alpha}{2}}$ (where $\beta^* = 1/2$)

3) $\boldsymbol{W_C^* = \frac{2W_L+2pS+\alpha S}{2-2p-\alpha}}$

Proof of equilibrium police allocation post-surveillance (Equation 4):

1) $W_{C,post}^{1} = W_{C,post}^{2}$

2) $\frac{W_L + (p+\beta\alpha+\delta)S}{1-p-\beta\alpha-\delta} = \frac{W_L + (p+(1-\beta)\alpha)S}{1-p-(1-\beta)\alpha}$

3) $(W_L + pS + \alpha S + \delta S)(1 - p - \alpha + \beta\alpha) = (W_L + pS + \alpha S - \beta\alpha S)(1 - p - \beta\alpha - \delta)$

4) $-\alpha W_L + \beta\alpha W_L + \beta\alpha S + \delta S = -\beta\alpha W_L - \delta W_L + \alpha S - \beta\alpha S$

5) $2\beta\alpha W_L + 2\beta\alpha S = -\delta(W_L + S) + \alpha(W_L + S)$

6) $\beta = \frac{-\delta(W_L+S)+\alpha(W_L+S)}{2(\alpha W_L+\alpha S)}$

7) $\beta = \frac{(\alpha-\delta)(W_L+S)}{2\alpha(W_L+S)}$

8) $\boldsymbol{\beta^* = \alpha - \delta/_{2\alpha}}$

Proof of equil. criminality threshold post-surveillance (Equation 5):

1) $W_C = \frac{W_L + (p+\beta\alpha+\delta)S}{1-p-\beta\alpha-\delta}$

2) $W_C = \frac{W_L + \left(p+(\frac{\alpha-\delta}{2\alpha})\alpha+\delta\right)S}{1-p-(\frac{\alpha-\delta}{2\alpha})\alpha-\delta}$

3) $W_C = \frac{2W_L + 2pS+\alpha^2-\delta^2+\delta^2 S}{2-2p-(\alpha-\delta)-2\delta}$

4) $\boldsymbol{W_C^* = \frac{2W_L + 2pS+\alpha S+\delta S}{2-2p-\alpha-\delta}}$

Proof of increase in criminal threshold from surveillance (Equation 6):

1) $\Delta W_C = W_{C,post}^* - W_{C,pre}^*$

2) $\Delta W_C = \frac{2W_L + 2pS+\alpha S+\delta S}{2-2p-\alpha-\delta} - \frac{2W_L+2pS+\alpha S}{2-2p-\alpha}$

   a. **Numerator:** $4W_L - 4pW_L - 2\alpha W_L + 4pS - 4p^2S - 2p\alpha S + 2\alpha S - 2p\alpha S - \alpha^2 S + 2\delta S - 2p\delta S - \alpha\delta S - (4W_L - 4pW_L - 2\alpha W_L - 2\delta W_L + 4pS - 4p^2S - 2\alpha pS - 2p\delta S + 2\alpha\delta - 2\alpha pS - \alpha^2 S - \alpha\delta S$

   b. **Denominator:** $4 - 4p - 2\alpha - 4p + 4p^2 + 2\alpha p - 2\alpha + 2\alpha p + \alpha^2 - 2\delta + 2p\delta + \alpha\delta$

3) $\Delta \boldsymbol{W_C = \frac{2\delta(W_L+S)+2\delta W_L}{4p^2+\alpha^2+2p\delta+\alpha\delta+4p\alpha-4\alpha-8p-2\delta+4}}$

9.2 Appendix B: Additional empirical specifications

I also examine the effect of surveillance on crime by block fixed effects to control for time-invariant unobservables and quarter fixed effects to control for time trends. With these time and individual effects removed, I obtain the difference-in-differences estimator of the surveillance effect based on the model that:

$$Crime_{it} = \alpha + \beta_1(Treatment_{it}) + \beta_2(Crime_{i,t-1}) + Q_t + F_i + \varepsilon_{it}$$

where $Crime_{it}$ is the number of criminal offenses (disaggregated by crime type in repeated specifications) in block i in quarter t; $Treatment_{it}$ is coded 1 in all quarters t in which block i has a camera (either constructed or fully operational), and 0 otherwise; $Crime_{i,t-1}$ is a lag of the dependent variable; Q_t is a quarter fixed effect; F_t is a block fixed effect; and ε_{it} is the error term.

Introducing the lagged dependent variable into the right-hand side of the equation makes the model dynamic, allowing us to account for any impulse effect. The model is estimated both with and without this lagged variable. Table A1 presents the results of this fixed effects estimation. There is a positive and significant effect of treatment on property crimes. This is most likely a relic of the estimation, which ignores spatial correlation.

Table A1: Effect of camera installation on crime rates (fixed effects estimation)

	All Crime		**Property**		**Violent**	
	(1)	(2)	All property	Auto theft	All violent	Aggravated Assault
Installation of Camera	.486 (.092)	.407 (.095)	.370 (.091)	-0.016 (.057)	.038 (.025)	.048 (.024)
Lagged crime, by location	–	.044 (.006)	.044 (.006)	-0.011 (.006)	-.039 (.007)	-.027 (.007)
Constant	1.11 (.036)	1.239 (.037)	1.101 (.036)	.706 (.022)	.143 (.009)	.127 (.009)

Note: Standard errors in parentheses.