No. 9
FEBRERO DE 2017

Documentos CEDE

ISSN 1657-7191 Edición electrónica.

Edición especial CESED

The Deterrent Effect of Surveillance Cameras on Crime

Santiago Gómez
Daniel Mejía
Santiago Tobón

CESED Centro de Estudios sobre Seguridad y Drogas
CEDE Centro de Estudios sobre Desarrollo Económico
Universidad de los Andes Facultad de Economía

CESED
Centro de Estudios sobre Seguridad y Drogas

CEDE
Centro de Estudios sobre Desarrollo Económico

Universidad de los Andes
Facultad de Economía

Serie Documentos Cede, 2017-09
ISSN 1657-7191 Edición electrónica.
Actualizado en Mayo de 2019

© 2017, Universidad de los Andes, Facultad de Economía, CEDE. Calle 19A No. 1 – 37 Este, Bloque W.
Bogotá, D. C., Colombia Teléfonos: 3394949- 3394999, extensiones 2400, 2049
infocede@uniandes.edu.co
http://economia.uniandes.edu.co

Impreso en Colombia – Printed in Colombia

La serie de Documentos de Trabajo CEDE se circula con propósitos de discusión y divulgación. Los artículos no han sido evaluados por pares ni sujetos a ningún tipo de evaluación formal por parte del equipo de trabajo del CEDE.

El contenido de la presente publicación se encuentra protegido por las normas internacionales y nacionales vigentes sobre propiedad intelectual, por tanto su utilización, reproducción, comunicación pública, transformación, distribución, alquiler, préstamo público e importación, total o parcial, en todo o en parte, en formato impreso, digital o en cualquier formato conocido o por conocer, se encuentran prohibidos, y sólo serán lícitos en la medida en que se cuente con la autorización previa y expresa por escrito del autor o titular. Las limitaciones y excepciones al Derecho de Autor, sólo serán aplicables en la medida en que se den dentro de los denominados Usos Honrados (Fair use), estén previa y expresamente establecidas, no causen un grave e injustificado perjuicio a los intereses legítimos del autor o titular, y no atenten contra la normal explotación de la obra.

Universidad de los Andes | Vigilada Mineducación
Reconocimiento como Universidad: Decreto 1297 del 30 de mayo de 1964. Reconocimiento personería jurídica: Resolución 28 del 23 de febrero de 1949 Minjusticia.

The Deterrent Effect of Surveillance Cameras on Crime*

Santiago Gómez Daniel Mejía Santiago Tobón †

May 9, 2019

Abstract

From the US to Colombia to China, millions of public surveillance cameras are at the core of crime prevention strategies. Yet, little is known on the effects of surveillance cameras on criminal behavior. We study an installation program in Medellín and find that quasi-random allocation of cameras led to a decrease in crimes and arrests. With no increase in monitoring capacity and no chance to use camera footage in prosecution, the results suggest offenders were deterred rather than incapacitated. We find no evidence of close range negative or positive spillovers after the installation of the cameras. *JEL codes:* H41, K42

Keywords: surveillance cameras, deterrence, incapacitation, law enforcement, crime, Colombia

*We acknowledge support from the National Police of Colombia and the Department of Security of Medellin for granting access to data and internal procedures. For helpful comments, we thank Diego Amador, Chris Blattman, Adriana Camacho, Fabio Sánchez and Marcela Eslava. We are also grateful to numerous seminar and conference participants. Financial support was provided by the Administrative Department for Science, Technology and Innovation of the National Government of Colombia (COLCIENCIAS) and the Center for the Study of Security and Drugs at Universidad de los Andes (CESED).

†Gómez: Heidelberg University, Research Center for Enviromental Economics, santiago.gomez@awi.uni-heidelberg.de; Mejía: Universidad de los Andes, Economics & Office of the Attorney General of Colombia, dmejia@uniandes.edu.co; Tobón (corresponding author): University of Chicago, Pearson Institute and Harris Public Policy & Innovations for Poverty Action, Peace and Recovery Program, tobon@uchicago.edu.

El efecto disuasivo de las cámaras de seguridad sobre el crimen

Santiago Gómez   Daniel Mejía   Santiago Tobón †

Resumen

De Estados Unidos a Colombia a China, millones de cámaras públicas de seguridad se encuentran en el centro de estrategias de prevención del crimen. Sin embargo, se sabe muy poco sobre los efectos de estas cámaras sobre la conducta criminal. En este paper estudiamos un programa de instalación de cámaras en Medellín, y encontramos que la asignación cuasi-aleatoria de cámaras lleva a una disminución del crimen y los arrestos. Sin incrementos en la capacidad de monitoreo ni posibilidades de usar grabaciones en procesos judiciales, los resultados sugieren que los criminales fueron disuadidos y no incapacitados. No encontramos evidencia de efectos de desplazamiento positivos o negativos en rangos de distancia cortos.

1 Introduction

Many countries are installing large numbers of public surveillance cameras to help law enforcement agencies in preventing crime and violence. China alone will have more than 500 million surveillance cameras installed in 2020.[1] However, the extent to which surveillance cameras effectively reduce crime is still unclear and most of the evidence is restricted to a handful of highly developed countries. Moreover, when crime drops after cameras are installed, the mechanisms in play are also unclear.

In this paper, we study a large installation program of public surveillance cameras in the city of Medellín, Colombia. In particular, we look at changes in crime and arrest trends at camera locations and assess the extent of short-range spatial spillovers. We also dig into the institutional setting of the city to understand whether these cameras helped law enforcement agencies in incapacitating offenders, or rather deterred them from engaging in criminal behavior.

The empirical evidence regarding the effects of public surveillance cameras on crime is inconclusive. Welsh and Farrington (2009) present a systematic review of previous studies which we update in this brief summary. Some evaluations find significant reductions in crime rates ranging from 18 to 57 percent (Armitage et al., 1999; Ditton and Short, 1999; Blixt, 2003; Brown, 1995; Caplan et al., 2011; Gill and Spriggs, 2005; Griffiths, 2003; Ratcliffe et al., 2009; Skinns, 1998). Others find significant increases of as high as 24 percent (Brown, 1995; Farrington et al., 2007; Gill and Spriggs, 2005; Winge and Knutsson, 2003).[2]

However, most of these studies fail to control for the simultaneous determination of camera installation sites and crime hot spots, or suffer from methodological drawbacks that do not allow for a causal interpretation of the results. For instance, some studies focus on

[1] See media coverage by the BBC.

[2] Note Gill and Spriggs (2005) find different results for different locations. One study worth mentioning in more detail is Piza et al. (2012), which focus on the mechanisms. The authors compare case processing times and enforcement rates between crimes detected by camera footage and 911 calls for service. Results show a significant reduction in processing times by surveillance cameras, which provides evidence of an effect through an increase in the operational capacity of law enforcement agencies.

the time evolution of crime at intervened areas (Armitage et al., 1999; Blixt, 2003; Ditton and Short, 1999; Piza et al., 2012), some involve additional interventions along with the installation of public surveillance cameras (Skinns, 1998), some rely on small samples of as low as six cameras (Farrington et al., 2007; Gill and Spriggs, 2005; Ratcliffe et al., 2009; Winge and Knutsson, 2003), and some involve arbitrary selection of control areas (Brown, 1995; Caplan et al., 2011; Griffiths, 2003; Ratcliffe et al., 2009; Winge and Knutsson, 2003).

Two studies stand out with better methodological quality. Priks (2015) studies an installation program in the Stockholm subway system and finds that crimes dropped 25 percent at stations in the city center. However, most property crime displaced outside the stations with increases as large as 300 percent. Munyo and Rossi (2019) study a large installation program in the city of Montevideo and find a decrease in crime of about 20 percent in coverage areas, with positive spillovers to neighboring locations.[3]

Beyond adding one additional data point on studies on surveillance cameras, to the best of our knowledge, this is the first attempt to effectively disentangle the deterrent effects of public surveillance cameras on criminal behavior.[4] Broadly speaking, law enforcement policies can prevent crimes either by deterring or incapacitating offenders. These mechanisms entail different costs, and therefore understanding if one prevails over the other has relevant policy implications. To incapacitate an offender, the criminal justice system needs to identify, arrest, prosecute and incarcerate the person. Moreover, all these actions are taken after a crime has already been committed. A deterred offender, on the other hand, does not engage in crime and is not subject to all the costs in the criminal justice system stemming from the identification of the subject and further stages.

The literature on the identification of the deterrent effects of law enforcement can be split into two categories (Chalfin and McCrary, 2017): police manpower and severity of criminal sanctions. This paper studies a different kind of policy: the installation of public surveillance

[3]To identify causal effects, both studies exploit the variation in time and space in camera installation using difference-in-differences methods. We follow a similar approach in this paper.

[4]Other studies find evidence of the deterrent effect of sanctions for other kinds of anti-social behavior as drunk driving. See for instance Hansen (2015).

cameras. The main argument of the Becker (1968) and Ehrlich (1973) framework is that offenders decide to commit a crime by weighing the expected benefits and costs of engaging in a given criminal action. The presence of public surveillance cameras, as do increases in police or the severity of sanctions, rise these costs. There is some evidence on the deterrent effect of increases in police manpower (Greene, 2013; Levitt, 1998), as well as in sentence length (Drago et al., 2009; Helland and Tabarrok, 2007; Kessler and Levitt, 1999; Zimring et al., 2001), although the latter is less clear and has been controverted (Raphael, 2006; Webster et al., 2006).[5]

We estimate the causal effect of the surveillance cameras on criminal behavior by exploiting the temporal and spatial variation in the installation of roughly 450 cameras in Medellín. A main concern that arises is the possible endogeneity of the allocation of surveillance cameras with respect to crime. As with other law enforcement policies, governments decide to allocate resources—in this case surveillance cameras—at crime hot spots. This decision may not be orthogonal to unobservable characteristics of the hot spots that also affect crime control outcomes. We address this issue by following different approaches, detailed below.

Our analysis relies on the fact that pre-selected hot spots were not ranked nor prioritized beforehand and the installation procedure was based upon bureaucratic and logistical considerations. A total of 587 places were simultaneously selected for camera installation, but the cameras were not installed at once. Instead, most of them were progressively put operational over a period of two years between May 2013 and April 2015. By the end of this period, 448 out of 587 new cameras were installed and the remaining 139 were still projected for installation with no exact dates.[6]

Each installed camera had its own post and street signals noting its presence. Moreover, the number of camera operators remained constant at 12 people over the total installation

[5] Raphael (2006) and Webster et al. (2006) directly question the results from Kessler and Levitt (1999). Levitt (2006) replies back to Webster et al. (2006).

[6] Before this process started, 383 cameras were already operational in the city. All of them were installed prior to 2012 but exact dates of installation are not available. The 139 pending cameras were progressively installed during 2018 along with additional places in a process that involved the prioritization of crime hot spots. Therefore, we restrict our analysis to the 587 places originally selected.

period. This implies that before the process to install the new cameras started there were about 32 cameras per operator and after the installation of the new 448 cameras there were about 69.

By using the exact dates of installation and geo-located data on crime and arrests, we build a panel data for which the cross sectional units are buffers of 120 meters surrounding the camera installation sites and the time series units are months.[7] The variation in the timing of installation as well as the high frequency occurrence of crimes and arrests at each location, allow us to control for unobservable time invariant characteristics at crime hot spots as, for instance, the ability of police patrols at the location or environmental factors that favor or un-favor crime occurrence.[8] We estimate the effect of public surveillance cameras on crime and arrests by following a difference-in-differences approach over multiple time periods.

We use administrative records in our analysis. The National Police of Colombia provided the data on reported crimes and arrests. Each case specifies exact coordinates, date and type of reported crime or arrest as being related to either property or violent crime. The Department of Security of Medellin provided the data on location coordinates and times of installation of all public surveillance cameras. We assigned a crime or arrest to a camera if it fell within a 120 meters buffer around the camera. Whenever a crime or arrest lied on two camera buffers the decision rule was to assign it to the closest camera.

Our difference-in-differences estimation suggests there is a reduction in crime reports following the installation of the cameras. This effect is statistically significant at conventional levels. In our preferred specification, the coefficient of interest shows a reduction of 0.09 standard deviations in reported crime levels, which is equivalent to a 24 percent decrease relative to the average reported crime level in the year before the installation started. We

[7]The technical specifications from the Department of Security of Medellin indicate that the high quality range of the cameras is 120 meters.

[8]Police directives in Colombia dictate that surveillance police patrols are expected to remain for at least two years at a specific location. Even though the timing is probably not an exact match to the period of installation of the surveillance cameras, the cycle length points at some stability in the expected ability of police patrols at one place.

also find a reduction of 0.07 standard deviations in arrest levels. The magnitude of the coefficient is equivalent to a 32 percent decrease, relative to the average arrest levels during the year before the installation started.

We assess the validity of our approach in different ways. First, we study whether the common trends assumption holds. The causal interpretation of the results hinge on the assumption that crime and arrest trends among hot spots with and without cameras were the same before the installation process started. Our setting, however, is rather singular as the treatment and control groups change as more cameras are installed at selected locations. Thus, we assess the validity of this assumption by estimating a hypothetical installation of surveillance cameras between May 2011 and April 2013, mimicking the exact order and months of installation with a lag of two years. This estimation serves as both an assessment of the common trends assumption and a falsification test. We find the effect of these hypothetical cameras on crime and arrests to be not significant at conventional levels and economically unimportant in size, relative to the coefficient estimates when we consider the actual dates of installation.

Second, despite the robustness of our results to controls on idiosyncratic characteristics of the crime hot spots, there may still be unobserved aspects of these locations that are correlated with crime control in general. For instance, there may be targeted municipal plans that progressively intervene crime at specific locations and are not captured either by the installation site or time fixed effects. We rule out these threats by looking at the effect of the installation of surveillance cameras by type of crime. As most violent crimes are fights that result from un-planned situations, we hypothesize that the deterrent effect of the cameras should be stronger on property crimes which require some level of planning (see Priks, 2015)). Our results are consistent with this hypothesis and show deterrent effects mainly on property crime. Indeed, the effects of the installation of surveillance cameras on violent crime and arrests are negligible.

Third, we also assess the sensitivity of our results to alternative buffer radiuses and the assumptions on the distribution of crime data when estimating ordinary least squares regressions. On one hand, we study whether changes in the specified area of coverage of the camera are driving our results. If it is the case that the cameras have a deterrent effect regardless of the possibility of camera operators to actually use them, the inclusion of smaller or larger areas of coverage should still be consistent with deterrence. On the other hand, as crimes and arrests are counts, we estimate the same difference-in-difference models with poisson regressions. Our results remain robust to these alternative specifications.

Furthermore, we study spatial spillover effects by looking at the effect of surveillance cameras on crime at neighboring areas. Geographically focused interventions as the installation of surveillance cameras may result in the displacement of offenders to other—presumably less costly in utilitarian terms—areas of the city. We find no changes in reported crimes at conventional levels of statistical significance. It remains to be assessed if the deterrent effect of surveillance cameras on criminal behavior at hot spots is offset by a spillover effect to farther locations. This situation, although still consistent with the deterrence mechanism, entails different policy implications. Our setting, however, does not allow us to identify a causal link to other geographical areas.

To the extent that crime control policies are costly and that deterring potential offenders is perhaps socially desirable over incapacitating them, these results favor the installation of public surveillance cameras for crime control. However, there are some additional questions that need to be addressed before reaching a more robust conclusion. First, the overall assessment of this policy hinges on the existence of spillovers and whether, if even present, crime displacement outweigh the direct benefits at crime hot spots. Even if our results do not point in that direction, we cannot rule out longer distance spillovers or non-spatial spillovers.

Second, even if there are no spillovers and the overall effect of installing surveillance cameras is an aggregate reduction of crime city-wide, there may be more efficient alternatives. These could range from hot spots policing to "broken widows"-type interventions to investments in criminal investigation. Any of these could eventually be more cost-effective.

Finally, our results are similar in sign and magnitude to the Priks (2015) and Munyo and Rossi (2019) studies, which we deem methodologically superior than others finding more conflicting results. However, there remains the question of the optimal number of surveillance cameras to be installed in a city, as there may be decreasing returns when the number of cameras is sufficiently large.

2 Theoretical framework and potential mechanisms

The economic approach to crime introduced by Becker (1968) and Ehrlich (1973) suggests that criminals behave rationally. In this setting, offenders decide to pursue criminal activities whenever they find the expected benefits of committing a crime to be higher than the expected costs. In particular, a rational offender would engage in a criminal activity if the expected benefits of committing a crime on the left hand side of the inequality below outweigh the expected costs on the right hand side:

$$(1 - p_q)\, U_{cq} - p_q S_q > U_l$$

where q refers to a specific geographical area, in this case a crime hot spot. We define $p_q \equiv r_q(m) + t_q$, with $r_q(m)$ being the sum of the actual probability of arrest, the actual probability of prosecution given arrest and the actual probability of sentencing given prosecution, which are specific to the enforcement capacity at hot spot q. We assume $r_q(m)$ to be a strictly increasing function of the monitoring capacity m. On the other hand, we take t_q as a deviation attributed to perceptions on the probabilities in $r_q(m)$ which are specific to the environmental setting at hot spot q. U_{cq} is the utility derived from crime at hot spot q. S_q is the (dis)utility derived from the sanction if the offender is effectively arrested at hot spot q, prosecuted and sanctioned, and U_l is the utility derived from legal labor or the opportunity cost of crime.

The installation of surveillance cameras is one alternative way to decrease the expected benefits of criminal activities through a number of ways:

1. The objective certainty of punishment can rise by means of changes in the probability of arrest, the probability of prosecution given arrest, or the probability of sentencing given prosecution. These are changes in r_q in the inequality. The probability of arrest at hot spot q can increase because of improved surveillance.

2. The probability of prosecution and sentencing provided the arrest was at hot spot q can increase because of the possibility to use camera footage as evidence during prosecution and trial. In practice, changes in r_q are changes in the operational capacity of the criminal justice system.

3. The subjective certainty of punishment may also increase because of improved perception of surveillance by the authorities. These are changes in t_q, the perception that offenders have on the actual enforcement capacity of the authorities, and imply a pure deterrent effect specific to hot spot q.

4. The severity of punishment could increase if evidence collected from camera footage at hot spot q results in aggravated sentences. These are changes in S_q in the inequality.[9]

This theoretical setting has three implications. First, if there are effects of public surveillance cameras on both reported crime and arrests, and these effects are in the same direction, it is likely that changes in r_q are not driving the effect. Second, if the monitoring capacity of public surveillance cameras (m) decreases or, put it simple, the probability that a camera operator is using the right camera and pointing in the right direction when a crime occurs is low, it is also unlikely that an effect of public surveillance cameras on crime are driven by changes in r_q. Finally, if the sentence scheme remains constant, the effect of public surveillance cameras on crime through changes in S_q is only possible if there is enough time for the criminal justice system to actually arrest, prosecute and sentence an offender.

[9]For instance, some judicial systems consider longer prison sentences whenever violence is used in committing a crime. If proof of violence use comes from camera footage, there would be a direct effect on the severity of punishment.

3 Setting

In this section we describe some institutional characteristics of the system of public surveillance cameras in Medellín. These characteristics are relevant to understand the prevailing mechanism for these cameras to have an effect on crime. In the first sub-section we describe the Integrated System for Security and Emergencies in Medellin and some especial characteristics of how public surveillance cameras operate. In the second sub-section we describe how the selection and installation process for the new group of public surveillance cameras, the ones we evaluate, took place.

3.1 The Integrated System for Security and Emergencies

Public surveillance cameras in Medellin are part of the Integrated System for Security and Emergencies known as SIES-M for its Spanish acronym. This system comprises five sub-systems. First, the 123 calls for service line which works similar to the 911 line in the US. Second, a set of global positioning system (GPS) devices for police patrols that trigger red flags when abnormal situations are observed. For instance, when patrols move at high speed or leave their area of jurisdiction. Third, the network of centers for strategic police information located at each police station in the city. Fourth, a network of community alarm buttons. And finally, the sub-system of interconnected public surveillance cameras.

As of mid 2015, the sub-system of public surveillance cameras had 831 cameras connected and 139 cameras pending installation. Of the 831 cameras, 383 were installed prior to 2012 with no data available on dates of installation. By 2013, a group of 587 locations was selected for new camera installations. Of those, 448 were installed between May 2013 and April 2015 with the remaining 139 uninstalled until 2018.[10] The technical characteristics of the cameras allow operators to observe criminal activities in detail whenever the camera is pointing in the direction of such situation. The cameras have high definition with optical zoom of up

[10]These cameras were installed in 2018 along with a new large group of cameras. The installation process involved especial targeting for crime hot spots, hence we restrict our analysis to the selected places at 2013 and the data up until 2015.

to 22x. This implies the camera can magnify the scene up to 22 times larger. In practice, this means that camera operators can see with good quality up to 120 meters around the camera installation site. Public surveillance cameras can turn 360 degrees horizontally and 270 degrees vertically, they all have night vision and are connected to the network by optical fiber and radio frequency.

Throughout the installation period, the sub-system of public surveillance cameras was operated by 36 people divided in three eight-hour shifts of 12 people each. Four of them were civilians hired by the Department of Security and eight were police personnel. The number of camera operators was not changed when new cameras were installed. This implies that by the beginning of 2013 there were about 32 cameras per operator while after the installation of the new 448 cameras took place there were about 69. Put it differently, the probability that a camera operator was using the right camera and pointing in the right direction when a crime occurred was low and, moreover, it decreased by more than half as the new group of cameras was installed. The sub-system has the capacity to store five years of data on camera footage, which is made available for criminal investigations under specific requests.

3.2 The Installation of New Public Surveillance Cameras

The new group of 587 sites for new cameras was selected in early 2013. The selection and installation process took place in three stages.

First, the office of the Information System for Citizen Security of the Department of Security of Medellin identified 587 candidate locations for camera installations. They used quantitative data on the amount and location of historical reported crimes, the location of the 383 previously installed cameras, and the number of additional cameras available, then a geographic information system software suggested the exact location for new installations. Specifically, they used a component of Q-GIS, a free and open source geographic information system software. This component was originally designed for the selection of new points of sale for commercial businesses, using as inputs the demand, previously operational points of sale and budget availability for new ones. Thus, they mirrored its operation to select locations for new camera installations. Of most importance, these places were not ranked nor prioritized by the software but merely suggested as an un-ordered list.

Second, field teams from the National Police and the local liaisons of the Department of Security made on-site validation visits in order to determine the exact locations for new installations. These teams validated whether the suggested locations were actually crime hot spots and not places with high crime reports due of bias on the location of some crimes. For instance, there are hospitals with a large number of reported homicides because injured people dies there, or places nearby metro stations where people report thefts when indeed they were robbed inside railcars before stepping down. Also, these teams verified whether there were trees, power cables or other operational problems regarding the installation, and selected the exact places of installation for the cameras taking into account these limitations.

Finally, there was the administrative process for the installation and set up of each public surveillance camera. This stage consisted in five main activities:

1. Requesting of an installation permit from the Planning Office of the city government, which must issue a favorable technical concept regarding the provision of most public goods

2. Requesting of an installation permit from the Transit Authority of the city government. This office must review any public goods that use or interfere with traffic infrastructure such as traffic lights and stop or crossing lines

3. Requesting of an installation permit from the environmental authority whenever the process involved cutting off trees or any other environmental concern

4. Requesting of power and internet connections from local companies

5. After all other activities are finished, requesting of physical installation and final connectivity tests from local contractors.

4 Data and Empirical Strategy

In this section we describe the data and present our empirical strategy to identify the effects of public surveillance cameras on reported crime and arrests.

4.1 Data

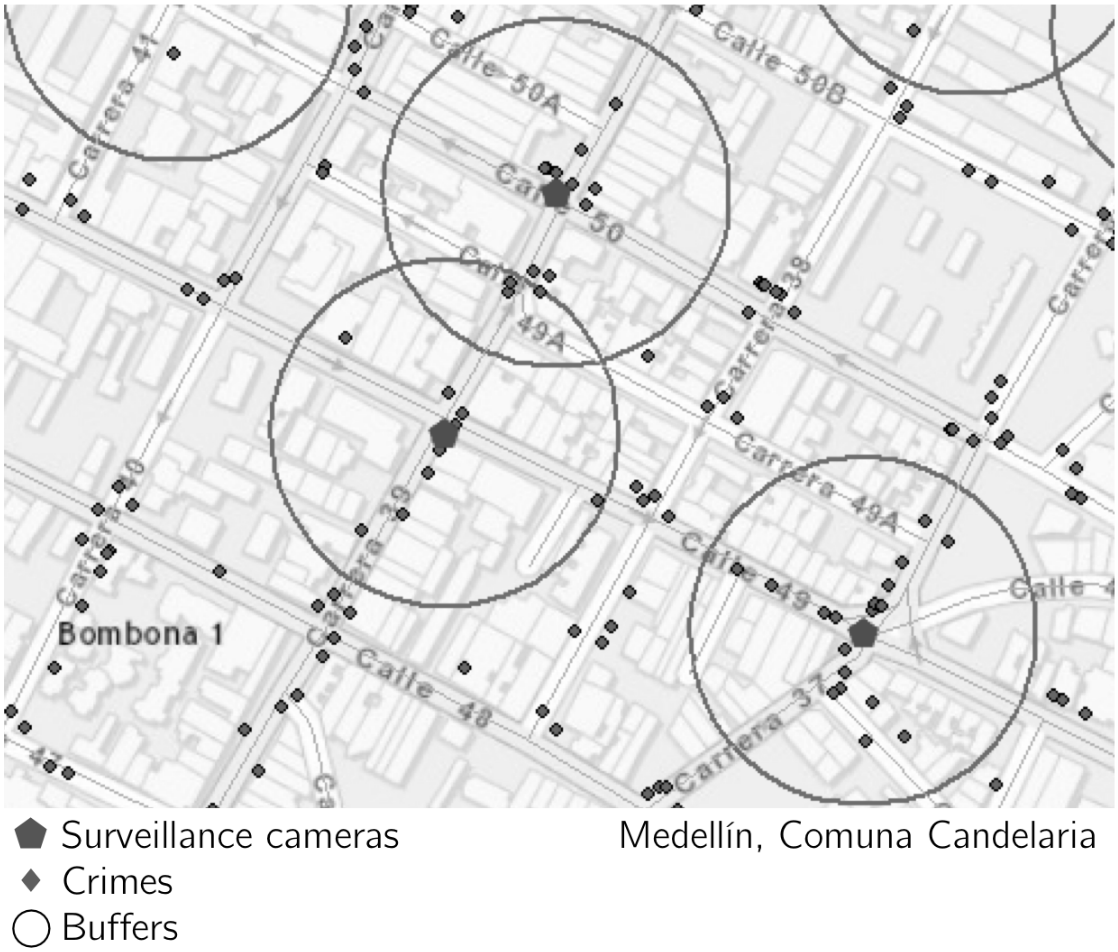
To study the effects of public surveillance cameras on crime we use two different data sources. First, we use data on reported crimes and arrests from the National Police of Colombia. Through 2013 crimes were reported with their approximate address and we obtain their coordinates by using a geo-locator add-on from a geographic information system software.[11] From 2014 onwards, the National Police registers specific coordinates for each crime using a proprietary software available at police stations and other reporting places. For both reported crimes and arrests we have exact dates and type of crime. We group homicide and assault cases in a violent crime category and all thefts and robbery cases in a property crime category.

Second, we have data on the location and dates of installation of a group of 587 public surveillance cameras. Out of those, 448 were installed between May 2013 and April 2015 and the remaining 139 had the dates of installation pending. These cameras came in addition to 383 previously installed cameras that were operational before 2012. For those 383 previously installed cameras we do not have dates of installation and hence we leave them out of our analyses. All information regarding the cameras and technical facts is from the office of the Information System for Citizen Security of the Department of Security of Medellín. Since the approximate recommended operation of the cameras is 120 meters, our units of analysis are buffers around camera installation sites of this radius.

We merge data from camera installation sites and reported crimes and arrests. We match a camera and a crime or arrest if the event falls within the 120 meters buffer of the camera.

[11] Specifically, we use a geolocator add-on for ArcGIS which uses the address to obtain specific coordinates. Because of imprecise address data, about 75 percent of all reported crimes matched a location.

Figure 1: Units of analysis. Buffers around camera installation sites



Notes: The figure depicts buffers around the location of public surveillance cameras. Data is from the government of Medellín and the National Police of Colombia.

For those cases in which one crime or arrest falls within the intersection of two buffers, we match the event to the closest camera site. Figure 1 details geographic information on surveillance cameras, crimes and buffers.

Table 1 presents summary statistics for monthly reported crimes and arrests at 587 camera installation locations for the installation period. This includes data from May 2013 through April 2015. On average, there were 0.8 reported crimes at each camera installation site per month, with a maximum of 31 and a minimum of 0. Most of the reported crimes at these places were property crimes. Also, there were about 0.2 arrests at each camera installation site per month, with a maximum of 9 and a minimum of 0. As for reported

Table 1: Summary statistics. Observations are buffers at camera installation sites × months during the installation period (two years)

	Obs. (1)	Mean (2)	S.D. (3)	Min (4)	Max (5)
A. Reported crimes					
Total crime	14,088	0.776	1.567	0	31
Property crime	14,088	0.659	1.446	0	31
Violent crime	14,088	0.116	0.471	0	22
B. Arrests					
Total arrests	14,088	0.173	0.583	0	9
Property crime arrests	14,088	0.129	0.510	0	9
Violent crime arrests	14,088	0.044	0.244	0	5

Notes: The sample includes data from May 2013 through April 2015 for the installation period. Data is for 587 camera installation sites at 120m buffers and month. Reported crime levels and arrests are from the National Police. Geolocation of camera installation sites is from the office of the Information System for Citizen Security of the Department of Security of Medellin. Violent crime includes reported homicides and assaults. Property crime includes all kinds of theft.

crimes, there were more arrests for property crimes than for violent crimes.

4.2 Empirical Strategy

We compare reported crimes and arrests at camera installation sites by using the difference-in-difference estimator for multiple time periods. In particular, we use ordinary least squares to estimate equation (1) below:

$$y_{it} = \beta D_{it} + \alpha_i + \gamma_t + \varepsilon_{it} \tag{1}$$

where i is a buffer at each camera installation site and t is the time period measured in months. y_{it} is a measure of reported crimes or arrests at place i and time period t. D_{it} is a dichotomous variable that takes the value 1 if there is a camera in operation at place i and time period t. α_i and γ_t stand for place and time fixed effects, respectively. Place fixed effects allow us to control for idiosyncratic characteristics of camera installation sites as, for instance, the ability of police patrols at the location or environmental factors that favor or un-favor crime occurrence. In turn, time fixed effects allow us to control, for instance, for time based public policies. ε_{it} is an error term clustered at the camera installation site level.[12] We also include year and month of the year fixed effects to control for seasonal monthly trends and year specific social, economic or political factors. β is the coefficient of interest. In this setting, from the first month of installation onwards we have treated groups of sites with surveillance cameras and control groups of sites without them. These groups change as more cameras are installed.

There are two identifying assumptions at the core of our empirical strategy. First, we argue that, restricted on the sample of all selected installation sites, the timing of installation is exogenous to unobserved characteristics of these places which are also correlated with reported crime levels and arrests.[13] Put it differently, we argue the setting creates a quasi-experimental design. We rely on two arguments to support this assumption. First, the selection procedure does not rank nor prioritize the locations. Hence any order of installation is, at least in principle, not based on crime levels. Second, timing for all permits and logistics necessary to carry out the installations was mainly driven by bureaucratic activities and bottlenecks in each office involved in the process. Both arguments were emphasized by officials from the Department of Security of Medellín in several interviews between November 2014 and June 2015. Furthermore, we conduct a formal test of the correlation of reported crime levels and actual dates of installation by estimating equations (2) through (4) below:

$$R_{it} = \eta_0 y_{it-1} + \alpha_{0i} + \gamma_{0t} + \varepsilon_{0it} \tag{2}$$

$$R_{it} = \eta_1 \frac{1}{6} \sum_{k=t-6}^{t-1} y_{ik} + \alpha_{1i} + \gamma_{1t} + \varepsilon_{2it} \tag{3}$$

[12] In particular, we estimate standard errors robust to heterostedasticity (Huber, 1967; White, 1980), allowing for arbitrary correlation within events of the same cluster (Froot, 1989).

[13] See sub-section 3.2 for further details.

$$R_{it} = \eta_2 \frac{1}{12} \sum_{k=t-12}^{t-1} y_{ik} + \alpha_{2i} + \gamma_{2i} + \varepsilon_{3it} \quad (4)$$

where R_{it} indicates the exact month of installation of camera i, i.e. it takes the value 1 if camera i is installed at month t, 0 before the installation and we impute a missing value from the second month of installation onwards. In these specifications, η_0, η_1 and η_2 measure the extent to which previous reported crime levels determine the timing of the installation of a camera. These estimations allow us to study whether reported crime levels for the previous month, and the averages for the previous six or twelve months influence camera installation dates. As in equation (1), $\alpha's$, $\gamma's$ and $\varepsilon's$ stand for place and time fixed effects, and error terms clustered at the camera installation site level, respectively.

Table 2 presents the results of this test. We are interested in looking at any correlation between reported crime levels in the pre-installation period and the actual dates of installation. If pre-selected sites were not ranked nor prioritized as the office of the Information System for Citizen Security of the Department of Security of Medellín informed us, and indeed the order of installation was driven by the bureaucratic process that followed the selection, there should be no apparent correlation. The results show that we cannot reject the hypothesis that previous crime did not affect installation dates at conventional levels of statistical significance.

Second, we argue that the common trends assumption holds. To support this assumption, we also conduct a formal test. In a standard difference-in-difference approach there are treatment and control units that keep their treatment status both before and during the intervention. In such a case, when data is available, the comparison of pre-treatment trends would be a straightforward way to test this assumption (usually presented as event studies). Our setting is different than those standard approaches in the sense that all our units of analysis start being controls and most of them move to the treatment condition progressively as the cameras are installed. Thus, we test the common trends assumption by estimating a falsification test.

Table 2: Correlation between pre-installation reported crime levels and timing of the installation of the cameras

	1 if camera installed								
	Controls are for total crime			Controls are for property crime			Controls are for violent crime		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crime_{t-1}	0.003			0.003			0.002		
	[0.002]			[0.002]			[0.005]		
6 months m.a. of crime		0.008			0.007			0.021	
		[0.005]			[0.006]			[0.015]	
12 months m.a. of crime			0.003			0.005			-0.005
			[0.010]			[0.012]			[0.031]
Buffer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,993	7,993	7,993	7,993	7,993	7,993	7,993	7,993	7,993
Groups	587	587	587	587	587	587	587	587	587
Adjusted R^2	0.086	0.086	0.085	0.085	0.085	0.085	0.085	0.085	0.085

Notes: The dependent variable is an indicator of the exact month of installation of a camera in each site, i.e. it takes the value 1 in the month the camera is installed and 0 before the installation. We impute a missing value from the second month of installation onwards. m.a. refers to moving average. The sample includes data from May 2013 through April 2015. Data is for 587 camera installation sites. Reported crime levels and arrests are from the National Police. Geolocation of camera installation sites is from the office of the Information System for Citizen Security of the Department of Security of Medellin. Violent crime includes reported homicides and assaults. Property crime includes all kinds of theft. All specifications include a non reported constant. * significant at the 10 percent, ** significant at the 5 percent, *** significant at the 1 percent.

In particular, we estimate equation (1) but instead of looking at the May 2013 - April 2015 period, we pre-date the installation of the cameras two years. For instance, if a camera was installed in June 2013, we take it as being installed in June 2011 in this estimation. Therefore, the time window included in this test is from May 2011 through April 2013. If it is the case that the changing treatment and control groups had a similar behavior in the pre-installation period, we should not observe any statistically significant relation between the falsified treatment and reported crimes and arrests. Table 3 presents the results. This estimation shows that we cannot reject the hypothesis of similar reported crime and arrest levels between changing treatment and control groups before the actual installation of the cameras took place.

5 Results

In this section we present our results. First, we present the estimation on the effects of public surveillance cameras on reported crimes and arrests as well as a sensitivity analysis. Then, we present the results for the analysis on short range spillovers to neighboring areas.

5.1 The Effects of Public Surveillance Cameras on Crimes and Arrests

Table 4 presents our baseline results. Columns (1) through (3) present estimates of the effect of public surveillance cameras on reported crimes, and columns (4) through (6) present estimates of the effect of public surveillance cameras on arrests. Columns (1) and (3) consider total crime or arrests. Columns (2) and (5) consider reported crimes and arrests related to property crime events, which includes all kinds of theft and robbery cases. And columns (3) and (6) consider reported crimes and arrests related to violent crime events, which includes homicide and assault cases. All regressions show the effect of camera installations on a standardized measure of the outcome.

Table 3: Falsification test. Effects of pre-dated installation of public surveillance cameras on reported crimes and arrests

	Reported crime			Arrests		
	Total crime	Property crime	Violent crime	Total crime	Property crime	Violent crime
	(1)	(2)	(3)	(4)	(5)	(6)
Pre-dated camera installation	0.003	-0.011	0.048	-0.018	-0.015	-0.012
	[0.021]	[0.020]	[0.037]	[0.022]	[0.022]	[0.023]
Buffer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,088	14,088	14,088	14,088	14,088	14,088
Groups	587	587	587	587	587	587
Adjusted R^2	0.039	0.040	0.004	0.004	0.003	0.001

Notes: The dependent variables are standardized reported crimes or arrests. The treatment variable is a two years pre-dated installation of public surveillance cameras. The sample includes data from May 2011 through April 2013. Data is for 587 camera installation sites. Reported crime levels and arrests are from the National Police. Geolocation of camera installation sites is from the office of the Information System for Citizen Security of the Department of Security of Medellin. Violent crime includes reported homicides and assaults. Property crime includes all kinds of theft. All specifications include a non reported constant. * significant at the 10 percent, ** significant at the 5 percent, *** significant at the 1 percent.

Results in column (1) suggest there is a positive effect of public surveillance cameras on reported crimes. This effect is statistically significant at the 5 percent level. The coefficient implies that the installation of a public surveillance camera, on average, drives reported crimes down by 0.09 standard deviations. Relative to the one year average during the pre-installation period in reported crime levels for our sample, the magnitude of this coefficient is a decrease of 24 percent in the number of reported crimes. Results in column (4) suggest there is also a positive effect of public surveillance cameras on arrests. This effect is also statistically significant at the 5 percent level and the coefficient implies the installation of a public surveillance camera, on average, drives arrests down by 0.07 standard deviations. Relative to the one year average during the pre-installation period in arrest levels, the magnitude of the coefficient implies a decrease of about 32 percent in the number of arrests.

As we described in sub-section 2, along with the facts that: (i) the monitoring capacity of the system of public surveillance cameras is low and decreased from 32 cameras per operator at the beginning of the installation period to 69 cameras per operator at the end; and (ii) the two year installation period is unlikely to allow for these public surveillance cameras to be used by the criminal justice system for aggravated sentences; these results suggest that the effect of public surveillance cameras on crime that we observe are not driven by an increase in the operational capacity of the criminal justice system, and rather can be attributed to a deterrent effect at the locations subject to intervention.

The concern that there may still be unobserved aspects of these locations that are correlated with crime control in general, however, remains present. For instance, there can be targeted plans from the local government that progressively intervene crime at specific locations, and in turn, these may not be captured either by the camera installation site or time fixed effects.

We rule out these threats by looking at the effect of the installation of public surveillance cameras by type of crime. Our argument is the following. As most violent crimes in the camera installation areas are assault and homicide cases resulting from fights and un-planned situations rather than instrumental violence, we hypothesize that the deterrent effect of the public surveillance cameras should be stronger on property crimes which require some level of planning and respond more directly to rational behavior. Results from column (2) show that there is a positive effect of public surveillance cameras on property crime. On average, reported property crime drops by 0.09 standard deviations when a surveillance camera is installed. This effect is statistically significant at the 5 percent level. In turn, results from column (5) show there is also a positive effect of public surveillance cameras on arrests related to property crimes. On average, arrests related to property crime cases drop by 0.06 standard deviation when a surveillance camera is installed. The coefficient is statistically significant at the 10 percent level. On the contrary, results from columns (3) and (6) show that the effects of the installation of public surveillance cameras on violent crime and arrests related to violent crime are negligible. In neither case we can reject the null hypothesis of no effect of the installation of public surveillance cameras under conventional levels of statistical significance. The difference between each pair of coefficients, however, is not significant and thus this evidence on differential effects of surveillance cameras for different types of crimes is rather statistically weak.[14]

We also assess the sensitivity of our results to the assumptions we imposed on the size of the buffer radius of 120 meters as recommended by the technical specifications for the cameras, and the distribution of reported crime and arrest data when we estimate ordinary least squares regressions. Table 5 presents the results. In columns (1) and (2), the units of analysis are buffers of 80 meters around the location of the cameras. Since the coverage area is smaller than that for 120 meters buffers, we use less information on reported crimes and arrests. The results for the effect of public surveillance cameras on reported crimes remain similar in both the magnitude of the coefficient and the significance level. Results for the effect of public surveillance cameras on arrests are still negative, but slightly smaller

[14]The p-value of a two tail test on the equality of the coefficients in columns (2) and (3) is 0.349. A one tail test for the coefficient in column (2) being more less than the coefficient in column (3) is 0.175. In turn, the p-value of a two tail test on the equality of the coefficients in columns (5) and (6) is 0.983. A one tail test for the coefficient in column (5) being more less than the coefficient in column (6) is 0.492.

Table 4: Baseline results. Effects of public surveillance cameras on reported crimes and arrests

	Reported crime			Arrests		
	Total crime	Property crime	Violent crime	Total crime	Property crime	Violent crime
	(1)	(2)	(3)	(4)	(5)	(6)
Camera installation	-0.091**	-0.087**	-0.038	-0.073**	-0.057*	-0.056
	[0.036]	[0.036]	[0.038]	[0.032]	[0.032]	[0.036]
Change from baseline	-23.5%	-26.8%	-12.2%	-31.5%	-28.5%	-40.8%
Buffer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,088	14,088	14,088	14,088	14,088	14,088
Groups	587	587	587	587	587	587
Adjusted R^2	0.024	0.021	0.005	0.005	0.004	0.002

Notes: The dependent variables are standardized reported crimes or arrests. The treatment variable takes the value 1 if a camera is installed in the corresponding place and month. Changes from baseline are measures of the magnitude of the coefficient relative to the one year average of the outcome variable in the pre-installation period. The sample includes data from May 2013 through April 2015. Data is for 587 camera installation sites. Reported crime levels and arrests are from the National Police. Geolocation of camera installation sites is from the office of the Information System for Citizen Security of the Department of Security of Medellin. Violent crime includes reported homicides and assaults. Property crime includes all kinds of theft. All specifications include a non reported constant. * significant at the 10 percent, ** significant at the 5 percent, *** significant at the 1 percent.

in magnitude and less precise. We attribute the loss of significance to the decrease in power resulting from the use of less information.

In columns (3) and (4), the units of analysis are buffers of 140 meters around the location of the cameras. In this case, since the coverage area is larger than that for 120 meters buffers, we use more information on reported crimes and arrests. The effects of public surveillance cameras on both reported crimes and arrests remain similar in magnitude and significance levels to our baseline results with 120 meters buffers. These results strengthen our hypothesis on the loss of power as an explanation for the change in precision we observe for arrests when using buffers of 80 meters.

Finally, in columns (5) and (6) we estimate the effects of public surveillance cameras using 120 meters buffers, but instead of estimating ordinary least squares regressions we use reported crime and arrests counts as outcomes and estimate the same difference-in-difference specification for poisson regressions. The results are consistent in the direction and significance of the coefficient of interest. We observe a drop in both reported crimes and arrests with the installation of public surveillance cameras. The coefficients are significant at the 5 percent level in both cases. The magnitudes in this case have a direct interpretation. The coefficient of the poisson regressions is interpreted as the expected difference in logs of expected counts for a change in a location from having no camera to having a surveillance camera operational, with all remaining characteristics constant. With this interpretation, the expected drop in crime is 12 percent and the expected drop in arrests is 18 percent with the installation of a public surveillance camera.[15]

5.2 Short Range Spatial Spillovers

A common concern with geographically focused crime interventions is that of negative spillovers to other areas. In this sub-section we study the extent of short range spatial spillovers on reported crimes.

[15] To reach these numbers we build incidence rate ratios, which are just e^d with d being the estimated coefficient. The magnitude of the change is the incidence rate ratio minus one.

Table 5: Sensitivity analysis. Effects of public surveillance cameras on reported crimes and arrests

	Buffer radius of 80m.		Buffer radius of 140m.		Poisson regressions	
	Reported crime	Arrests	Reported crime	Arrests	Reported crime	Arrests
	(1)	(2)	(3)	(4)	(5)	(6)
Camera installation	-0.087**	-0.048	-0.079**	-0.073**	-0.128**	-0.192**
	[0.037]	[0.033]	[0.036]	[0.032]	[0.059]	[0.097]
Buffer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,088	14,088	14,088	14,088	13,704	10,512
Groups	587	587	587	587	571	438
Adjusted R^2	0.019	0.004	0.026	0.007	.	.

Notes: The dependent variables are standardized reported crimes or arrests except for columns (5) and (6) for which the outcome variables are reported crime and arrest counts. Columns (1) and (2) have buffers of 80m. around the location of the cameras as units of analysis. Columns (3) and (4) have buffers of 140m. around the location of the cameras as units of analysis. Columns (5) and (6) are poisson regressions with the baseline buffers of 120m. around the location of the cameras as units of analysis. The treatment variable takes the value 1 if a camera is installed in the corresponding place and month. The sample includes data from May 2013 through April 2015. Data is for 587 camera installation sites. Reported crime levels and arrests are from the National Police. Geolocation of camera installation sites is from the office of the Information System for Citizen Security of the Department of Security of Medellin. All specifications include a non reported constant. * significant at the 10 percent, ** significant at the 5 percent, *** significant at the 1 percent.

In the theoretical framework from section 2, spillovers are a result of offenders that usually commit crimes at hot spot q deciding to move to other hot spot because a camera was installed there. This situation is still consistent with a pure deterrent effect of the cameras as the offender is deterred from committing crimes at the place where the camera was installed. One important point to highlight is that, at least in the theoretical framework we propose, even in the presence of spillovers aggregate crime should still decrease. This comes from the fact that if a rational offender preferred hot spot q to any other hot spot q' before a public surveillance camera was installed in hot spot q, then it must be the case that the benefits from crime at hot spot q were higher than the benefits from crime at hot spot q', or:

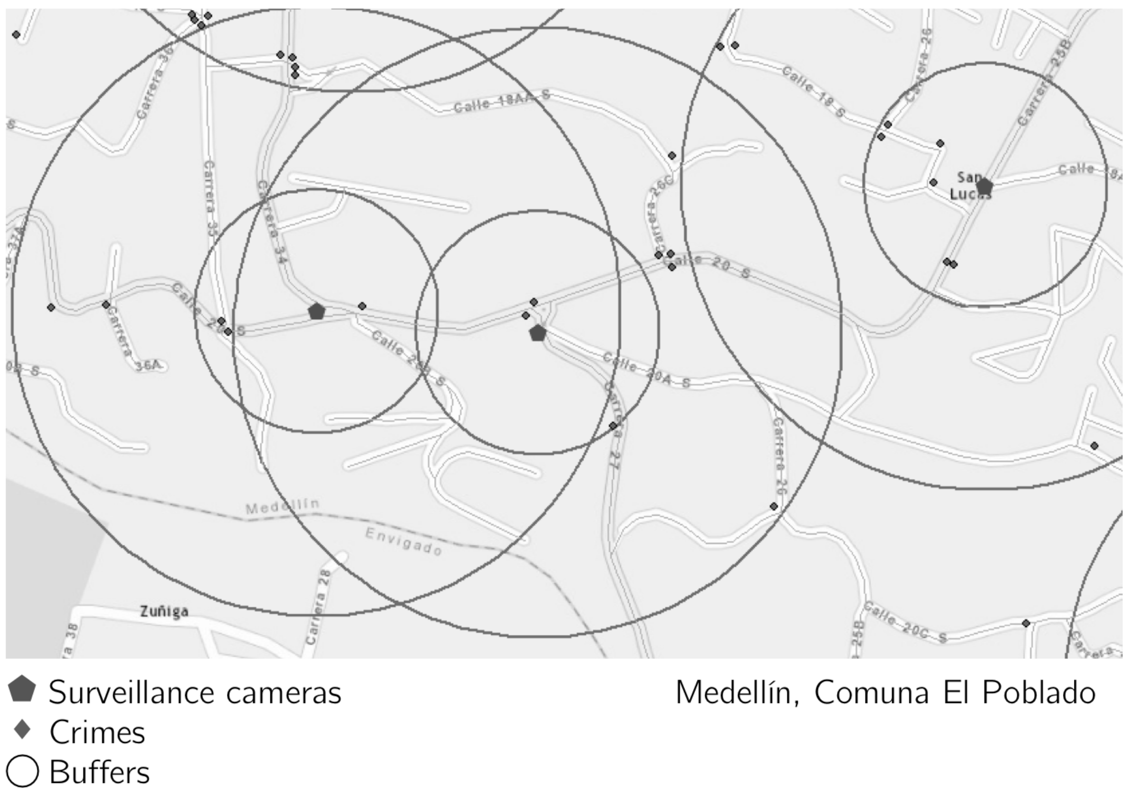
$$(1 - p_q)U_{cq} - p_q S_q \geq (1 - p_{q'})U_{cq'} - p_{q'} S_{q'} \text{ for any hot spot } q' \neq q$$

which in turn implies less crimes should be committed if the offender moves from hot spot q to hot spot q' after a camera is installed in hot spot q.

Our setting, however, does not allow us to identify long range spillovers and therefore we restrict the analysis to look at short range spillovers in neighboring areas to our sample of pre-selected places for camera installation. In particular, to assess crime spillovers we build inner and outer buffers at each camera installation site as shown in figure 2 and look at changes in reported crime in the areas between the inner and outer buffer (the donuts) of treated and control units. Whenever a reported crime is between the inner and outer buffers of a camera installation site, and the inner buffer of another surveillance camera, we consider this crime to be at the inner buffer of this last camera and therefore is not included in the displacement analysis. In other words, our space of analysis is composed by the union of donuts around camera installation sites minus the union of inner buffers of all cameras.

Table 6 presents the results. Columns (1) through (3) look at the effect of public surveillance cameras on reported crimes in the area between 120 and 300 meters around camera installation sites. Columns (4) through (6) look at the effect of public surveillance cameras on arrests in the area between 120 meters and 300 meters around camera installation sites.

Figure 2: Units of analysis. Inner and outer buffers around camera installation sites



Notes: The figure depicts buffers around the location of public surveillance cameras for displacement analysis. Data is from the government of Medellín and the National Police of Colombia.

In all cases, for total, property and violent reported crimes, we cannot reject the null hypothesis of no effect of the public surveillance cameras at conventional levels of statistical significance. This is, we find no evidence on crime or arrests spillovers nor on diffusion of benefits to surrounding areas.

We acknowledge that this spillover analysis is limited, mainly due to methodological constraints. As Blattman et al. (2018) show, the spillover analysis tend to bias both the results and the standard errors.[16] Our setting, however, does not allow to implement alternative specifications that correct for such problems.

6 Conclusions

In this paper we investigate the deterrent effects of public surveillance cameras on crime. To do so, we benefit from a quasi-experiment in the city of Medellin, Colombia that resulted from the installation of 587 public surveillance cameras between 2013 and 2015. We also propose a brief theoretical setting that allow us to identify the prevailing mechanism for the public surveillance cameras to have an effect on crime.

Our results show a reduction of about 24 percent in reported crimes following the installation of the public surveillance cameras relative to the one year average of reported crimes during the pre-installation period. We also observe a reduction of about 32 percent in arrests following the installation of the cameras relative to the one year average of arrests during the pre-installation period. These are local effects to pre-selected locations for the installation of surveillance cameras. Along with the facts that the monitoring capacity of the system of public surveillance cameras is low and decreased during the installation period, and the two year installation period is unlikely to allow for the public surveillance cameras to be used by the criminal justice system for aggravated sentences, these results suggest that the effects of the surveillance cameras on reported crimes are driven mainly by a deterrent effect at the locations subject to intervention. We provide evidence on the main identifying

[16] See also Collazos et al. (2019)

Table 6: Spillover analysis between 120 and 300 meters. Effects of public surveillance cameras on reported crimes at neighboring areas

	Reported crime			Arrests		
	Total crime	Property crime	Violent crime	Total crime	Property crime	Violent crime
	(1)	(2)	(3)	(4)	(5)	(6)
Camera installation	0.057	0.056	0.021	0.039	0.026	0.036
	[0.037]	[0.038]	[0.047]	[0.037]	[0.039]	[0.038]
Buffer fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,088	14,088	14,088	14,088	14,088	14,088
Groups	587	587	587	587	587	587
Adjusted R^2	0.021	0.017	0.008	0.008	0.008	0.001

Notes: The dependent variables are standardized reported crimes or arrests. Columns (1), (2) and (3) have donuts of 120 to 300 meters around the location of the cameras as units of analysis and the outcomes are standardized reported crimes. Columns (4), (5) and (6) have donuts of 120 to 300 meters around the location of the cameras as units of analysis and the outcomes are standardized arrests. The treatment variable takes the value 1 if a camera is installed in the corresponding place and month. The sample includes data from May 2013 through April 2015. Data is for 587 camera installation sites. Reported crime levels and arrests are from the National Police. Geolocation of camera installation sites is from the office of the Information System for Citizen Security of the Department of Security of Medellin. Violent crime includes reported homicides and assaults. Property crime includes all kinds of theft. All specifications include a non reported constant. * significant at the 10 percent, ** significant at the 5 percent, *** significant at the 1 percent.

assumptions: (i) the exogeneity of the timing of installation to unobserved characteristics of pre-selected places, and (ii) the common trends assumption for our difference-in-difference specification. Therefore, we believe a reasonable interpretation of our estimate is a causal relationship. Importantly, we do not find any crime or arrests spillovers to surrounding areas nor we observe any diffusion of benefits to these places.

We take these results as being suggestive for public surveillance cameras to be a worthwhile investment for cities, at least in contexts similar to Medellin. However, relevant questions remain to be answered in order to generate more robust evidence and to address the issue of external validity. In particular, even if our results suggest there are no immediate spillovers, we think it is relevant to look at the effects of the installation of public surveillance cameras on a longer range. This is important as the cost benefit analysis of such investments hinges on the assumption that overall crime would go down. In the presence of long range spillovers this may not be true. Non-spatial spillovers are also relevant. Comparing the aggregate effects of the installation of surveillance cameras to other competing policies as hot spots policing or "broken windows"-type interventions is also relevant in reaching an adequate cost-benefit analysis of crime control policies. Finally, the question of how many cameras should a city have is also unclear. Most certainly, there is a large enough number up until which there are decreasing returns and investments may no longer be worthwhile.

References

Armitage, R., G. Smyth, and K. Pease (1999). Burnley CCTV evaluation. *Surveillance of public space: CCTV, ... 10*, 225–249.

Becker, G. (1968). Crime and punishment: An economic approach. *Journal of Political Economy 76*(2), 169–217.

Blattman, C., D. Green, D. Ortega, and S. Tobon (2018). Place-based interventions at scale:

The direct and spillover effects of policing and city services on crime. *NBER Working Paper No. 23941*.

Blixt, M. (2003). The use of surveillance cameras for the purpose of crime prevention (English summary).

Brown, B. (1995). CCTV in Town Centres: Three Case Studies.

Caplan, J. M., L. W. Kennedy, and G. Petrossian (2011). Police-monitored CCTV cameras in Newark, NJ: A quasi-experimental test of crime deterrence. *Journal of Experimental Criminology 7*(3), 255–274.

Chalfin, A. and J. McCrary (2017). Criminal Deterrence: A Review of the Literature. *Journal of Economic Literature 55*(1), 5–48.

Collazos, D., E. Garcia, D. Mejia, D. Ortega, and S. Tobon (2019). Hotspots policing in a high crime environment: An experimental evaluation in Medellin. *Documento CEDE 2019-1*.

Ditton, J. and E. Short (1999). Yes, It Works, No It Doesn't: Comparing the Effects of Open-Street CCTV in Two Adjacent Scottish Town Centres. *Surveillance of Public Space: CCTV, Street Lighting and Crime Prevention 10*, 201–223.

Drago, F., R. Galbiati, and P. Vertova (2009). The Deterrent Effects of Prison: Evidence from a Natural Experiment. *Journal of Political Economy 117*(2), 257–280.

Ehrlich, I. (1973). Participation in Illegitimate Activities: A Theoretical and Empirical Investigation. *Journal of Political Economy 81*(3), 521.

Farrington, D. P., M. Gill, S. J. Waples, and J. Argomaniz (2007). The effects of closed-circuit television on crime: Meta analysis of an English national quasi-experimental multi-site evaluation. *Journal of Experimental Criminology 3*(1), 21–38.

Froot, K. A. (1989). Consistent Covariance Matrix Estimation with Cross-Sectional Dependence and Heteroskedasticity in Financial Data. *Journal of Financial and Quantitative Analysis 24*(3), 333–355.

Gill, M. and A. Spriggs (2005). Assessing the impact of CCTV. Home Office Research Study, London.

Greene, E. (2013). COPS and Cuffs. In P. Cook, S. Machin, O. Marie, and G. Matrobuoni (Eds.), *Lessons from the Economics of Crime. What Reduces Offending (CESifo Seminar Series)*. Cambridge, MA: The MIT Press.

Griffiths, M. (2003). *Town centre CCTV: An examination of crime reduction in Gillingham, Kent.* Ph. D. thesis, University of Reading.

Hansen, B. (2015). Punishment and deterrence: Evidence from drunk driving. *American Economic Review 105*(4), 1581–1617.

Helland, E. and A. Tabarrok (2007). Does Three Strikes Deter? A Nonparametric Estimation. *Journal of Human Resources 42*(2), 309–330.

Huber, P. J. (1967). *The behavior of maximum likelihood estimates under nonstandard conditions.* Berkeley, CA: University of California Press.

Kessler, D. and S. D. Levitt (1999). Using Sentence Enhancements to Distinguish Between Deterrence and Incapacitation. *The Journal of Law and Economics 42*(April), 343–364.

Levitt, S. D. (1998). Juvenile Crime and Punishment. *The Journal of Political Economy 106*(6), 1156–1185.

Levitt, S. D. (2006). The Case of the Critics Who Missed the Point: A Reply to Webster et al. *Criminology and Public Policy 5*(3), 449–460.

Munyo, I. and M. Rossi (2019). Police-monitored cameras and crime. *Economic Journal 125*(The Scandinavian Journal of Economics), Forthcoming.

Piza, E. L., J. M. Caplan, and L. W. Kennedy (2012). Is the Punishment More Certain? An Analysis of CCTV Detections and Enforcement. *Justice Quarterly* (September), 1–29.

Priks, M. (2015). The Effects of Surveillance Cameras on Crime: Evidence from the Stockholm Subway. *Economic Journal 125*(588), F289–F305.

Raphael, S. (2006). The Deterrent Effects of California'S Proposition 8: Weighing the Evidence. *Criminology and Public Policy 5*(3), 471–478.

Ratcliffe, J., T. Taniguchi, and R. Taylor (2009). The Crime Reduction Effects of Public CCTV Cameras: A Multi-Method Spatial Approach. *Justice Quarterly 26*(4), 746–770.

Skinns, D. (1998). Doncaster CCTV surveillance system: Second annual report of the independent evaluation.

Webster, C., A. Dobb, and F. Zimring (2006). Proposition 8 and Crime Rates in California: The Case of Disappearing Deterrent. *Criminology and Public Policy 5*, 417–448.

Welsh, B. C. and D. P. Farrington (2009). Public Area CCTV and Crime Prevention: An Updated Systematic Review and Meta Analysis. *Justice Quarterly 26*(4), 716–745.

White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity.

Winge, S. and J. Knutsson (2003). An Evaluation of the CCTV Scheme at Oslo Central Railway Station. *Crime Prevention and Community Safety: An International Journal 5*(3), 49–59.

Zimring, F., G. Hawkins, and S. Kamin (2001). *Punishment and Democracy: Three Strikes and You're Out in California*. New York: Oxford Univerity Press.