Police Presence, Rapid Response Rates, and Crime Prevention[1]

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Abstract

This paper estimates the impact of police presence on crime using a unique database that tracks the exact location of Dallas Police Department patrol cars throughout 2009. To address the concern that officer location is often driven by crime, my instrument exploits police responses to calls outside of their allocated coverage beat. This variable provides a plausible shift in police presence within the abandoned beat that is driven by the police goal of minimizing response times. I find that a 10 percent decrease in police presence at that location results in a 7 percent increase in crime. This result sheds light on the black box of policing and crime and suggests that routine changes in police patrol can significantly impact criminal behavior. *JEL* Codes: D29, K42.

1 Introduction

Does police presence deter crime? While it was once generally accepted that the role of police officers was apprehending criminals after they committed a crime, today there is a growing body of research that shows that increased investment in policing results in lower crime rates.[1] Specifically, previous papers have found that larger police forces and high doses of police presence in small areas result in lower crime rates (see Levitt (1997), Evans and Owens (2007), Di Tella and Schargrodsky (2004), and Draca et al. (2011)). However, the literature has largely ignored the fact that the rapid response philosophy where police officers are spread thinly throughout the city and much of an officer's time is dedicated to responding to emergency calls remains the dominant patrol strategy applied by police departments in the US and worldwide. This paper examines the impact of this rapid response strategy on deterrence. More specifically, will adding additional officers to the current patrol system have any impact on crime?

Since the 1930s, police patrol in US cities has been dominated by the rapid response system. Simply stated police agencies have patrol cars drive around in police beats ready to respond rapidly to an emergency call. When they are not responding to such calls they spend their time in what has been termed random preventative patrol, showing their presence in the beats to deter offending (see Kelling & Moore, 1988). The random preventative patrol philosophy came under significant criticism after an experiment conducted over 4 decades ago, the Kansas City Policing Experiment, failed to find any impact of increased preventative patrol on crime.[2] While some argue that this

[1] See surveys of the literature conducted by Cameron (1988) , Marvell and Moody (1996), Eck and Maguire (2000), and Chalfin & McCrary (2017) and micro geographic interventions by Sherman & Weisburd (1995), Braga et al. (1999), Di Tella and Schargrodsky (2004), Gould and Stecklov (2009), Nagin (2013), Weisburd et al. (2015), and MacDonald et al. (2016).

[2] This experiment took place between October 1972 and September 1973 in the South District of Kansas, Missouri. The experiment divided the 15 beats of this district into three areas: "reactive" where police only entered the area to respond to calls, "proactive" where police visibility was increased to 2 to 3 times its baseline level of patrol, and "control" areas where the baseline level of patrol from before the experiment was maintained.

could be a result of implementation as there is no evidence regarding the actual dosage of police presence received by treatment and control areas, there is no denying that this study left its mark on the literature.[3]

Today, innovative crime prevention programs tend to focus on high dosages of deterrence in small areas or over short time periods (e.g. hot spot policing, pulling-levers policing, police crackdowns), as well as community interventions via neighborhood policing or broken-windows policing.[4] These crime prevention techniques are often difficult to practice alongside a rapid response philosophy. Rapid response dictates a low dosages of police officers across the city, which makes officers unavailable for more concentrated crime prevention programs. My analysis, which uses a precise measure of the dosage of police presence throughout Dallas, Texas, suggests that we may have been too quick to embrace the conclusion that general shifts in patrol across a large city cannot significantly impact crime. Indeed, my analysis shows that preventative patrol in the context of a rapid response philosophy can provide significant deterrence of crime.

Analyzing the immediate impact of police presence on crime requires access to information on the location of police officers and crime over time. Such information has begun to be available because of the use of management information systems in policing that detail the exact locations (x y coordinates) of crime events, as well as Automobile Locator Systems (AVL) that track where police vehicles are when they patrol the city. While most police agencies now analyze data on crime events, the use of AVL systems to analyze where police patrol is rare and seldom integrated with crime data. In Dallas,

[3] See Larson (1975) for a review of concerns regarding the implementation of the Kansas City Experiment.

[4] See Braga (2012) and Telep & Weisburd (2012) for a review of current deterrence strategies. Pulling-levers policing targets a small number of chronic offenders, while hot-spots policing focuses on a small number of chronically crime ridden geographic locations. Police crackdowns take place by shifting large groups of police to focused areas. Broken windows policing aims to reduce public disorders before actual crime occurs. Neighborhood policing is a strategy where specific officers conduct activities in designated neighborhoods in order to create a consistent relationship between these officers and residents of that area.

Texas, over the course of 12 months (throughout 2009), AVL systems were active in all 873 police patrol vehicles and data on their location was saved and stored.[5] I focus on the beat (a geographic patrol area averaging 1.7 square miles in size) each car was allocated to patrol as well as where these officers were actually present throughout the day. Information on incidents of crime was acquired from a separate database that tracks calls for service (911 calls) placed by local citizens to the police department.[6] Thus, the current project is not motivated by a specific policing experiment, or large change in routine police activity, but rather, takes advantage of a large amount of data (roughly 100 million pings of information) to provide an estimate of the social returns of an additional hour of police patrol in the current policing system.

A deterrence mechanism that is based on police interactions would imply that areas or times of day with higher levels of police presence will report less crime. However, this ignores both the allocation of officers to riskier locations during riskier periods, and the fact that the occurrence of a crime is likely to increase police presence as officers are called to respond to the incident. Indeed, each year beat level police allocation in Dallas is based on calls for service and crime from previous years (using Staff Wizard software). Division commanders then adjust these allocation decisions based on weekly Compstat meetings where current crime concerns are discussed and areas in need of additional police attention are identified. This type of well managed police allocation would result in a positive correlation between policing and crime which is illustrated in Figure (1) .Generally, areas and times with higher levels of allocated patrol tend to have higher levels of both police presence and crime.[7] Thus, while this dataset provides a

[5]The AVL data does not include the location of officers on motorcycle and horseback (mounted division). The motorcycle patrol unit consists of 42 officers and the mounted division consists of 17 police officers.

[6]I separate calls that relate to crime into the following categories: violent crimes, burglaries, thefts, and public disturbances. I focus on 911 calls as they are less likely to suffer from reporting bias than reported crimes and are more likely to provide the exact time at which the incident occurred.

[7]While there are 873 Dallas patrol vehicles tracked in this study, on average there are 132 cars on

unique picture of police presence across a city, the location of officers may be determined by factors unobserved by the econometrician and correlated with crime.

My identification strategy stems from the two distinct responsibilities facing police patrol cars: proactive and reactive policing. While police may be allocated to a certain area (beat) in order to create a deterrence effect and lower the expected benefit of committing a crime, they are also responsible for answering emergency calls within their larger division quickly - generally, in under 8 minutes.[8] I use incidents that can result in patrol officers being assigned to calls outside of their area of patrol to capture an element of randomness regarding whether or not police are present at a given location and time. Thus, I introduce the *Outside Calls Ratio* (OCR) instrument, which is equal to the number of calls an officer patrolling this beat is likely to address outside of the beat. It is calculated as the ratio of outside calls to allocated outside patrol. The instrument is motivated by the idea that assignment to an outside beat is a function of both the density of outside calls and outside police presence. This measure is different from realized outside assignment which could be driven by crime risks at the beat level.

In order to ensure that the *Outside Calls Ratio* is not correlated with crime at the beat, I focus on outside 911 calls reporting incidents related to mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses. Reports of crime are not included in these outside calls in order to avoid the concern that crimes occurring across beats may be correlated. I also focus on out of beat patrol allocation as opposed to out of beat police presence. Out of beat police allocation is determined at the start of the shift as opposed to out of beat presence which

active patrol per hour. These cars are allocated among 232 beats at the beginning of their shift. Thus, the most common allocation points are either 0 or 1 car allocated per hour. The reason that police presence (defined by the location of police vehicle throughout the shift) does not have a 1-1 relationship with police allocation is that officers often spend time outside of their allocated coverage beat.

[8] A complete summary of the Dallas Police Department goals as well as performance can be found in the "Dallas Police Department Management and Efficiency Study" conducted by Berkshire Advisors (2004).

is immediately affected by the distribution of calls and crime. My results are robust to controlling for beat, month, day of week, and weekend$\times$hour of day fixed effects.

The main threat to the exclusion restriction for this proposed instrument is that even keeping outside calls constant, a decrease in out-of-beat patrol allocation will increase the *Outside Calls Ratio.* While this is likely to increase the probability that a local patrol officer will abandon his beat, one could be concerned that the decrease in out of beat patrol allocation was a result of a general decrease in crime concerns at the division level (both inside and outside the beat).[9] In this case, applying the *Outside Calls Ratio* could bias the estimated deterrence effect towards zero. To address this concern, I introduce an additional instrument of *Outside Calls*. This instrument is equal to the numerator of the *Outside Calls Ratio* and is a weighted sum of calls, unrelated to crimes, occurring within the division outside of the beat being currently patrolled. While, this instrument has a weaker first stage in terms of predicting police presence in the beat, the exclusion restriction is more compelling.[10]

My results suggest that the number of officers patrolling a beat has a significant impact on the probability of crime. I first demonstrate that as reported in previous studies, there is a positive correlation in the data between police presence and crime. This positive correlation remains significant even when controlling for beat and time fixed effects. This suggests that police departments may be able to quickly adjust police presence to changing crime risks within locations over time. It is only when instrumenting for actual police presence with either the *Outside Calls Ratio* or *Outside Calls* that I

[9] Alternatively, one could be concerned that a decrease in out of beat patrol allocation may be driven by an increase in police patrol within the beat as the division has a set number of officers to allocate. This would imply that the *Outside Calls Ratio* would be positively correlated with police presence. I therefore focus only on outside officers assigned to patrol in the sector where the outside call took place. Since there are roughly 5 sectors in each division the count of officers assigned to one sector should not define officer allocation in any given beat b. Indeed, the data show the opposite trend where an increase in the *Outside Calls Ratio* results in a decrease in police presence.

[10] In the analysis I interact the instrument with an indicator for division. This strengthens the first stage of the instrument so that it does not fall under the weak instruments category.

can identify a deterrence effect. I estimate that a 10 percent decrease in police presence results in a 7 percent increase in crime. I provide evidence that this result cannot be explained by displacement of crime to neighboring beats.

While police departments often consider rapid response times (minimizing the elapsed time between receiving an emergency call and responding to that call) to be one of the most important tools for solving crimes, criminologists argue that no evidence exists to support that claim (Sherman, 2013).[11] Not only have few studies examined the impact of rapid response times on solving crimes, but also no attempt has been made to measure how rapid response tools impact the deterrence capacity of the police. My results provides an estimate of both the deterrence created by routine police activities and the possible community safety costs of police officers dividing their time between preventing future crimes and responding to past crimes.

These results join an empirical literature on measuring deterrence that focuses on applying techniques to mitigate simultaneity bias. My estimated elasticities of -0.9 regarding the impact of a change in police presence on violent crime and -0.6 on property crime fall at the higher end of the range of elasticities of between -0.4 and -1 (violent) -0.3 and -0.5 (property) reported in previous work (see Levitt (1997 & 2002) and Evans and Owens (2007)).[12]

Both Levitt (1997 & 2002) and Evans and Owens (2007) applied instrumental variable strategies to estimate the elasticity of crime to police force size. Chalfin and McCrary (2017) raise concerns regarding weak instruments in these papers and point out that these studies show a wide range of estimates that are often not statistically

[11] The general embracement of rapid response policing is evident in the summary of "best practices in police performance measurement" provided by the Rand Corporation (Davis, 2012). Using data from the Kansas City Preventative Patrol Experiment, Kelling et al. (1974) found no impact of response times on solving crimes. However, Blanes i Vidal & Kirchmaier (2017) find that faster response times increase the likelihood of detecting crimes when using an instrumenting strategy based on the distance of the incident from police headquarters. Mastrobuoni (2015) reaches a similar conclusion when analyzing the outcomes of quasi-experimental variations in police presence in the city of Milan.

[12] See McCrary (2002) for some concerns regarding estimates produced in the Levitt (1997) paper.

significant at conventional confidence intervals. The instruments used in this research avoid this critique with first stage F statistics of above 40 for both the *Outside Calls Ratio* and *Outside Calls* instruments. The deterrence estimates reported in this paper also fall within much smaller confidence intervals.

An additional branch of the literature focuses on exogenous changes in police presence that are driven by threats or actual acts of terrorism (Di Tella and Schargrodsky (2004), Klick and Tabarrok (2005), Draca et al. (2011), and Gould and Stecklov (2009)). Di Tella and Schargrodsky (2004) and Draca et al. (2011) report smaller elasticities of crime with respect to police presence of between -0.3 and -0.4. Similarly, MacDonald et al. (2015) report an elasticity of crime with respect to police presence of -0.33 when examining an increase of 200 percent in police presence in the area surrounding the University of Pennsylvania campus. This estimate shrinks further when focusing on randomized experiments. Sherman & Weisburd (1995) found that doubling police patrol at hotspot locations in Minneapolis resulted in a 6 to 13 percent decrease in crime. Blattman et al. (2018) report that an intervention that included doubling police presence at high street segments in Bogota led to a decrease in city-wide crime of below 2 percent when accounting for spatial spillovers.

This paper offers a bridge between the detailed location specific data that is analyzed in randomized experiments and the aggregate data that is usually available at the city level. To the best of my knowledge, Blanes i Vidal & Mastrobuoni (2018) is the only other paper that attempted to look at the geographic distribution of police officers throughout an entire city using precise GPS level data on police location. They take advantage of a natural experiment where police spent an extra 10 minutes per week in a 200 meter radius of an area where a burglary was reported for the week following a burglary. Interestingly, they find no effect of this change in weekly level police patrol on crime. I focus on police presence at the hourly level within Dallas beats (averaging 2.7 kms^2) and examine whether or not routine changes in police behavior can have significant impacts on crime. One important difference between these two studies is that this project focuses on moving police away from an area they have chosen to patrol, while Blanes i Vidal & Mastrobuoni (2018) focus on sending officers to patrol a specific location.

This paper proceeds as follows. In the next section I introduce the data used for this project as well as my technique for measuring police presence. Section 3 discusses the empirical strategy and presents estimates of the impact of police presence on different types of crimes. Section 4 explores the mechanisms of deterrence that are driving my results. Section 5 concludes.

2 The Data

Dallas, Texas is the ninth largest city in the US, with roughly 1.2 million residents and 3,266 sworn police officers spread over 385 square miles. I use two separate Dallas Police Department (DPD) databases that provide information on the precise location of both crime and police in 2009. The DPD call database records the time and location of each report of crime to the department. The Automated Vehicle Locator (AVL) database tracks the location of police cars throughout the day. Together they provide an opportunity to understand how police presence impacts crime.[13]

Dallas is an ideal location for research using AVL data since it is mostly flat and thus, is able to provide fairly precise latitude and longitude points with minimal missing data. Dallas police patrol is divided into 7 patrol divisions (Central, North Central, Northeast, Northwest, South Central, Southeast, Southwest) which are each commanded by a deputy chief of police. Figure 2 provides a map of the city divided into divisions and beats. There is some variation in the characteristics of beats across different divisions in

[13] Using geographic mapping software I collect additional information on population size as well as miles of roads across different areas in Dallas. These data are combined with information on daily temperature, visibility, precipitation, sunrise, and sunset times in order to control for variability in the probability of crime over time.

the city as illustrated by Table 1. Beats in the Central division are smaller, averaging 0.6 square miles, while beats in other divisions average 1.8 square miles. Beats in the South Central division have a higher percentage of black residents, while beats in the Southwest have the highest percentage of Hispanic residents. Residents of the North Central division report higher incomes. These characteristics highlight the importance of focusing on crime outcomes at the beat level as different parts of the city may require different levels of police presence and face different crime risks.

The analysis is conducted on geographic beats at hour long time intervals. I use the call database to count the number of crimes called into 911 for each beat b and hour h. Focusing on 911 calls as opposed to crime reports is expected to lower concerns regarding selective reporting of incidents. While I cannot rule out the possibility that in certain beats crimes may not be called in to the police, this should not impact my results when controlling for beat fixed effects. A larger concern is whether the presence of a police car in an area may reduce calls to 911 as people can speak directly with the patrolling officer. Importantly, 911 is the generally accepted protocol for reporting crime. Beats average 1.7 square miles and roughly 40 minutes of patrol per hour, thus reporting via 911 will usually be significantly faster.[14]

The original database included 684,584 calls recorded throughout 2009 in Dallas, Texas. My final call database consists of 556,978 calls after removing duplicate calls and excluding calls that were classified as hang-ups. Details of the data cleaning process are in Appendix A. The main analysis focuses on 289,030 calls reporting incidents of crime. These crimes are classified into the following categories: public disturbances, burglaries, violent crimes, and theft.[15] Figure 3 illustrates how the number of crimes vary over time

[14] Using internal DPD data, a source from the Dallas Police Department estimated that roughly 90 percent of reported crimes are initiated via 911 calls. The remaining 10% are likely to be a combination of officer initiated calls (often related to traffic stops), sex assault victims (reporting from trauma centers, hospitals, colleges, and victims' advocates), as well as residents reporting both to patrol officers and arriving directly at the police station.

[15] A crime is classified as a burglary if it involves entering a structure with the intent to commit a

in different areas of Dallas. While crime in all areas tends to peak in May and plummet in December, there are also significant fluctuations in the crime rate throughout the year.

Beginning in the year 2000, Dallas police cars were equipped with Automated Vehicle Locators (873 tracked vehicles). These AVL's create pings roughly every 30 seconds with the latitudinal and longitudinal coordinates of these vehicles. Each ping includes the radio name of the vehicle which provides information on the allocation of the police vehicle. Thus, a ping with radio name A142 refers to a car that was allocated to patrol beat 142 during patrol A (during the $1st$ watch that takes place between 12 AM and 8 AM).[16]

The Automated Vehicle Locator Data also includes a report indicator for vehicles that are responding to a call for service. This indicator provides information on whether the vehicle is on general patrol or responding to a call. In contrast to an aggregate count of police officers per city, these data present an opportunity to map the activity of each individual squad car throughout the day.

The call database and Automated Vehicle Locator dataset are the actual data used by the Dallas police department to assign officers to 911 incidents. Thus, when a 911 call is placed in Dallas, the call taker records basic information on the incident (location, caller name, classification of incident, and time) and defines the severity of the incident. This information is loaded into the CAD (Computer Aided Dispatch) system which is the source for the call data. This incident then appears on the computer of the police dispatcher for the relevant division where the incident was reported.[17] The police dispatcher then assigns the incident to a patrol car based on priority (as recorded

crime inside. Stabbings, shootings, robberies, assaults, kidnappings, and armed encounters are classified as violent crimes. Public intoxication, illegal parking, suspicious behavior, prostitution, loud music, gun fire, speeding, road rage, and panhandlers are classified as public disturbances.

[16] Cars are often allocated to more than one beat, therefore the radio name serves as a proxy for allocation to a given beat. While, it would be preferable to have data on the exact allocation, this can still provide insight into the general area of allocation.

[17] Each of the 7 divisions has its own set of dispatchers.

in call data) and distance of car (as tracked in AVL data). When possible the incident is assigned to the police officer allocated to the beat of the incident, but since this officer can be otherwise occupied and most calls require two officers, officers are often assigned to out of beat calls. While, it is possible during severe emergencies for police dispatchers to coordinate and allocate officers across divisions, police are generally dispatched to calls within their division.

To create a database of police location, I divide the city of Dallas into 232 geographic beats of analysis and map each ping from the Automated Vehicle Locator Database (AVL) into a beat.[18] The vehicle pings are then used to count the minutes of police presence over each hour long interval of 2009. I define minutes of presence for each car as the elapsed time between first entrance and first exit from the beat. If the car exited the beat and later returned, it is categorized as a new first entry and first exit. Thus, a car that is present in beat 142 between 6:50 and 7:20 will contribute 10 minutes of presence in hour 6 and 20 minutes of presence in hour 7. If that same car returns to the beat at 7:30 and exits at 7:50, it will contribute 40 minutes of presence in hour 7. Only cars that were in a beat for at least 5 minutes of that hour can contribute to minutes of presence.[19]

Figures 4 and 5 illustrate the levels of both police allocation and actual presence across different parts of the city over time. While beats in the South receive a higher allocation of police officers than beats in the North, it is clear from Figure 5 that actual presence is higher in the North. My identification strategy builds around the idea that actual police presence over time is not fully determined by the allocation of officers.

Table 1 summarizes the mean hourly values for crime, police allocation and police presence by beat at the division level. The majority of crimes occur in beats that are

[18] The study focuses on 232 out of 234 beats in Dallas. Two beats were excluded from the analysis as they are composed primarily of water.

[19] I set a lower bound of presence at 5 minutes in order to focus the analysis on cars that were likely to be patrolling the given beat and not simply driving through the area.

located in the Southwest side of the city (with an average crime rate of 0.194). On average police officers are allocated to cover beats for 60 to 80 percent of each hour. The highest level of police allocation is in the North Central division where on average each beat has an allocated officer for over 80% of each hour, while in the Northwest division, a patrol officer is allocated to a beat for only about 60% of every hour. However, police allocation only refers to whether or not there was an active patrol officer at this hour of the day whose radio name referred to the given beat. Actual police coverage varies significantly from allocated coverage, with the largest average difference observed in the Southeast division. While allocated coverage is determined at the start of an officers shift, police presence is a function of the events and crime concerns that develop throughout the day.

The simultaneous relationship between police presence and crime is already made apparent in Table 1. Beats in the Northeast division average 30 percent less police presence than beats in the Southwest division, yet beats in the Southwest division report a higher crime rate. In order to identify a causal effect of policing on crime, I focus on an instrument that impacts the level of police presence in a given beat, but should not directly impact crime.

Outside Calls (OC_{bh}) are calculated for each beat (b) and hour (h) as a weighted average of the number of calls occurring in division D_b outside of beat b. Hour h is a time variable beginning at 0 at 12 AM on January 1st, 2009 and culminating at h =8736 at 11 PM on December 30th, 2009. Thus, I sum the number of 911 calls received in division D_b outside of beat b during hour h reporting incidents related to mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses. Importantly, instead of calls occurring in all k beats of the division being counted equally, OC_{bh} is a weighted sum,

$$OC_{bh} = \sum_{k \neq b \in D_b, h} n_{kh} w_{bk} \tag{1}$$

Where n_{kh} is the number of calls that occurred in beat k during hour h and w_{bk}

is the estimated probability that an officer in beat b will be assigned to a call in beat k (See Appendix B for a description of this process).

The *Outside Calls Ratio* (OCR_{bh}) divides the *Outside Calls* instrument from equation (1) by the number of officers allocated to patrol in the sectors surrounding the outside call beats.[20] In order to create this instrument, I calculate aggregate measures of police presence at the beat and sector level.

I define PA_{bh} as the amount of time (in hours) patrol cars were allocated to spend in beat b during hour h. The allocation of police vehicles (PA_{bh}) is determined by assignment at the start of their shift and is different from police presence (P_{bh}) which is a measure of where they actually patrol. For example, PA_{bh} would be equal to 1 at a beat and hour where one car was allocated to patrol, even when actual police presence (P_{bh}) was only 0.5 as the car was only physically patrolling the beat for 30 minutes of that hour. $Sector\_PA_{kh} = \sum_{j \in S_k, h} PA_{jh}$ is the amount of time (in hours) patrol cars were allocated to spend in the sector (S_k) surrounding beat k during hour h. $OPatrol_{bh}$ is calculated for each beat (b) and hour (h) as a weighted average of allocated patrol cars in the sectors within division D_b where calls took place,[21]

$$OPatrol_{bh} = \sum_{k \neq b \in D_b, h} Sector\_PA_{kh} \times n_{kh} \times w_{bk} \tag{2}$$

The variable $OPatrol_{bh}$ provides a weighted measure of the number of officers that are in the area surrounding beats where relevant outside calls occurred. This may affect the likelihood that an officer from beat b will abandon his beat.

I define the *Outside Calls Ratio* (OCR_{bh}) as,

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[20] The Dallas police department divides the city of Dallas into 7 divisions, where each division is split into sectors. Each sector is comprised of roughly 7 beats.

[21] $Sector\_PA_{kh}$ in equation (2) is a count of police allocation outside of the given beat b. Thus, when the sector of the outside call (k) is the same as that of the given beat b, $Sector\_PA_{kh} = \sum_{j \in S_k, h} PA_{kh} - PA_{bh}$.

$$OCR_{bh} = \frac{OC_{bh}}{OPatrol_{bh}} \tag{3}$$

In the next section I lay out my empirical strategy for estimating the deterrence effect of police presence on crime. I discuss unobserved factors that can create bias in estimating this effect and explain how the instruments address these concerns. My results illustrate that even with very detailed micro data, absent an exogenous shift in police presence, policing and crime remain positively correlated.

3 Empirical Strategy and Results

In equation (4) , I model the occurrence of a crime (C_{bh}) as a function of police presence (P_{bh}),

$$C_{bh} = x_{bh}\beta_0 + \beta_1 P_{bh} + \gamma_t + \eta_b + \varepsilon_{bh} \tag{4}$$

C_{bh} is a count of the number of 911 calls reporting incidents of crime (violent crimes, burglaries, thefts, and public disturbances) at beat b during hour h. The variables included in x_{bh} capture time varying environment characteristics that could impact the costs and benefits of crime (weather, visibility, etc.). The focus of my analysis is P_{bh}, a count of the amount of time police officers spent patrolling inside beat b at hour h. If one police vehicle was present for a full hour (h) at beat (b) then $P_{bh} = 1$. A single patrol car in the beat that was only present for 30 minutes will result in a P_{bh} value of 0.5, alternatively, 2 cars that were present over the entire hour will result in $P_{bh} = 2$. The time and beat fixed effects γ_t and η_b account for the differential probabilities in crime across different times and beats. If policing is uncorrelated with the remaining unobserved factors impacting crime (ε_{bh}) , then $\widehat{\beta}_1$ estimates the amount of deterrence created when police coverage is increased by 1 car.

My main concern regards the endogeneity of policing P_{bh}. It has been well documented in the literature that police allocation is far from exogenous. In a well functioning police department officer allocation will be highly correlated with crime. Using detailed geographic data can further complicate the relationship as one would expect that when a crime occurs in a given hour more police will immediately enter the beat in response to the crime. Even after removing cars that are specifically assigned to respond to the call, I cannot rule out a situation where additional officers may be drawn to the location of the crime incident for backup purposes. An additional concern is that there may be seasonal differences in crime risks that are addressed by the police force by means of changing police allocation across beats and time.

The Dallas Police Department has a stated goal of answering all serious 911 calls (priority 1) within 8 minutes and priority 2 calls (e.g. potential for violence or past robbery) within 12 minutes (Eiserer, 2013). Thus, the pre-planned allocation of an officer to a beat can be disrupted by an influx of emergency calls. It is exactly this differentiation between the endogenous choice of sending officers to higher risk crime locations and the plausibly random timing of emergency calls in surrounding areas that provide a first stage for police presence P_{bh},

$$P_{bh} = x_{bh}\alpha_0 + \alpha_1 OC_{bh} + \theta_t + \rho_b + \delta_{bh} \tag{5}$$

While the allocated level of presence can be determined by the perceived crime risk in that area (δ_{bh}), actual presence is impacted by an exogenous factor, *Outside Calls* (OC) as defined in equation (1). The estimated coefficient on the instrument ($\widehat{\alpha}_1$) is expected to be negative, since an increase in outside calls should decrease police presence in the beat (P_{bh}). Figure (6) shows that beats and intervals of time with a higher measure of *Outside Calls* (OC) have lower levels of police presence and higher levels of crime.[22]

[22] Outside calls is a weighted sum of outside incidents related to mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses.

Table (2) presents regression estimates for the general impact of the *Outside Calls Ratio* and *Outside Calls* on police presence as defined in equation (5). I find that increasing the *Outside Calls Ratio* by 1 decreases police coverage by 0.055 (s.e. 0.003) which is significant at the 1 percent level. Not surprisingly, without information on outside patrol, the precision of the instrument in predicting police presence in the beat decreases. Specifically, I find that an additional *Outside Call* decreases police presence by 0.078 (s.e. 0.026)). One explanation for this weaker response is heterogeneity across locations in their response to outside calls. While the *Outside Calls Ratio* takes into account that an officer is more likely to be assigned to an out of beat call when that call takes place in an area where police are spread thinly, this does not hold for the *Outside Calls* instrument. A source of heterogeneity could be that in areas and hours when police presence is more saturated, an increase in calls in a neighboring beat could actually bring more officers to the area as officers drive through on their way to respond to the call.

To maximize the flexibility of the *Outside Calls* instrument, I interact it with an indicator for police division. This allows different divisions to follow different protocols or face different constraints regarding between beat allocation. After including these interactions, the first stage F statistic on the *Outside Calls* instrument is 40.81. While an increase in the *Outside Calls Ratio* results in a significant decrease in police presence across all 7 divisions, the effect of *Outside Calls* is more varied and exhibits a positive effect on police presence in beats in the Central division that are typically small in size and very close together.[23] The instrumental variable analysis conducted in this paper always includes this interaction for the *Outside Calls* instrument.

I estimate the impact of police presence on all crimes using equation (4) for fixed

[23]While this does not impact the exclusion restriction, it could raise questions regarding the monotonicity assumption of the instrument. Note, however, that this will not create additional bias under the assumption that the average causal effect of police presence on crime is the same for the compliers (those for whom outside calls decrease police presence) and the defiers (those for whom outside calls increase police presence) (following Angrist, Imbens, and Rubin (1996)).

effects and 2SLS specifications. I compute heteroskedasticity and autocorrelation consistent standard errors for all specifications (see Conley (1999)). The focus of this paper is estimating β_1, the impact of an additional police vehicle in a given beat (b) and hour (h) on crime outcomes (C_{bh}). In the fixed effect model (column (1) of Table (3)) I find that an increase in police presence seems to imply an increase in crime even when controlling for weather as well as time fixed effects (month, day of week, and weekend$\times$hour) and beat fixed effects.[24] These results suggest that the presence of an additional police car at a given beat results in a significant 0.012 increase in crime (at an average crime rate of 0.15).

Two stage least squares estimates appear in columns (2) and (3) of Table (3). The estimate in column (2) measures the deterrence effect when actual police presence (P_{bh}) is instrumented with the *Outside Calls Ratio*, column (3) provides an estimate of the effect when applying the alternative *Outside Calls* instrument. These two stage least squares estimates provide an opportunity to measure deterrence without the simultaneity bias concerns in the OLS estimates (if more police are present at locations and times with increased crime risks this will result in a positive bias on the estimated deterrence effect $\left(\widehat{\beta}_1\right)$. The instrument allows me to focus on changes in police presence that were not a direct outcome of changes in perceived crime risks at the given beat and hour.

In specification (2) when instrumenting for police presence with the *Outside Calls Ratio* instrument, I find a significant negative effect of police presence on crime equal to -0.185 (0.032). While β_1 in equation (4) represents the effect of an additional police vehicle (P_{bh}) on crime, what is driving the estimate is the reality that cars are often withdrawn from their patrol beat when assigned to an outside call. Accordingly, a real world interpretation of this effect is that removing 60 minutes of presence from a given beat at a given hour results in a 123 percent increase in crime $\left(100 \times \frac{0.185}{0.15}\right)$. If I

[24] I control for weekend$\times$hour fixed effects in order to allow weekend hours to differ from weekday hours.

focus on average police presence per hour (36 minutes), a 10 percent decrease in police presence implies a 7.4 percent increase in crime (elasticity of -0.74).[25] I estimate a similar deterrence effect when applying the *Outside Calls* instrument (column (3)).

Table (3) also provides information on how different weather and time characteristics impact crime outcomes. I find that crime is more likely to occur during twilight. Higher temperatures increase the occurrence of crime, and bad weather lowers the probability of crime.

In Table (4) , I separately examine the impact of police on different types of crimes (violent crimes, public disturbances, burglaries, and theft).[26] I first report the measured effect of police presence in an OLS model that controls for month, day of week, weekend×hour, and beat fixed effects, as well as temperature, precipitation, twilight, holiday, and darkness. In specifications (2) and (3), I report results when instrumenting for police presence with the *Outside Calls Ratio* and *Outside Calls* instruments used in Table (3) .[27] All crime types exhibit a significant positive correlation between police presence and crime (see column (1)) that disappears when instrumenting for police presence with the *Outside Calls Ratio* and *Outside Calls* (see columns (2)-(3)).

The estimated deterrence effect of police presence on violent crime after instrumenting for police presence with the *Outside Calls Ratio* is similar to that of *Outside Calls*. These deterrence estimates of -0.094 (s.e. 0.017) and -0.098 (s.e. 0.028) translate to an elasticity of roughly 0.9.[28] While both instruments provide similar estimates of

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[25] This is calculated as $\frac{3.6}{60} \times 100 \times \frac{0.185}{0.15}$.

[26] I classify violent crimes as stabbings, shootings, robberies, assaults, kidnappings, and armed encounters. I classify public intoxication, illegal parking, suspicious behavior, prostitution, loud music, gun fire, speeding, road rage, and panhandlers as public disturbances.

[27] *Outside Calls* are defined in this paper as those reporting mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses.

[28] The deterrence impact on violent crimes was calculated by taking the estimated impact of an additional police vehicle on violent crime (-0.094 (*OCR*) & -0.098 (*OC*)) relative to the average violent crime rate of 0.065. Thus, the *OCR* (*OC*) instrument specification estimate implies that an additional police car results in an 144 (151) percent decrease in violent crime. Since the average amount of police presence is 0.6, a 10 percent increase in police presence requires dividing the full hour impact by 16.7.

the effect of police presence on public disturbances and burglaries, it is more noisily measured when applying the *Outside Calls* instrument. I find that a 10 percent increase in police presence decreases public disturbances by 6 to 7 percent, and burglaries by 5 to 6 percent. The effect of police presence on theft in Row D is much smaller and not statistically significant from zero when applying either of the instruments.

4 A Closer Look at the Mechanisms of Deterrence

My estimates suggest that police presence at the beat level can significantly impact crime. The next step is to understand the mechanism by which police presence changes behavior. What are patrol officers doing to prevent crime? Does police presence also impact non-crime related incidents? Are police officers more/less effective when allocated to certain areas? Does an increase in police presence at this beat displace crime to a neighboring beat?

Police officers engage in both active patrol (e.g. stops, questioning, frisks) and passive patrol (e.g. car patrol, paperwork) when working a beat. In order to correctly interpret my deterrence results, it is relevant to understand the extent to which outside calls impact active police patrol. This differentiation is important for gaining insight into whether or not an empty patrol car (or an officer who is simply filling out paperwork in his/her car) can have the same deterrence effect as an officer actively patrolling the streets. I therefore use arrests as a proxy for active police presence and examine how they are impacted by changes in police presence that are driven by out of beat calls.

Table (5) suggests that changes in police presence that are driven by out of beat calls may impact arrests. One interpretation of these results is that police are creating deterrence, not only by being present in the area, but actively reminding individuals that there are repercussions for criminal behavior. An alternative explanation could be that part of the deterrence effects presented in this paper may be a result of incapacitation,

This calculation is also applied to all other crime types.

where the individual arrested had planned to commit multiple crimes in that beat at that exact unit of time but due to police presence was arrested after the first attempt. If this is the mechanism through which incapacitation immediately impacts crime, then it is possible to measure a deterrence effect that is separate from incapacitation by estimating equation (4) focusing on how police presence (P_{bh}) impacts the probability of a crime as opposed to the number of crimes. In this specification, I continue to find a significant deterrence effect such that a 10 percent increase in police presence results in a 6.1 to 7 percent decrease in the probability of crime.[29] While this suggests that people may change their behavior due to the increased risk of penalty when police are present, I cannot rule out the possibility that some of this effect is driven by an arrest taking place before the individual had time to commit an additional crime.

In 2009, DPD received over 10,000 911 calls related to fires, suicides, abandoned children, and drug houses. While these incidents require police involvement, we would not expect them to respond to changes in police presence. Thus, these call categories provide an opportunity for a placebo test to ensure that the deterrence estimates reported in Tables (3) and (4) are driven by changes in police presence. Table (6) illustrates that unrelated calls that should not be sensitive to police officer patrol (suicides, abandoned children, fires, and drug houses) are not significantly impacted by police presence when applying both instruments.

If police presence impacts crime by providing a visual reminder of the costs of crime, I would expect larger beats, where officers are less likely to be seen, to be less affected by losing a police vehicle than smaller beats. In Table (7), I split the data into three groups of roughly equal sizes: small beats (less than 4.6 miles of roads), midsize beats (4.6 to 8 miles of roads), and large beats (more than 8 miles of roads). I find that

[29] The estimated coefficient on P_{bh} is -0.163 (s.e. 0.028) when applying the *Outside Calls Ratio* instrument and -0.141 (s.e. 0.034) when applying the *Outside Calls* instrument. The average probability of crime per beat and hour is 0.14 (s.d. 0.3) and the average amount of police presence is 0.605 (s.d. 1.08).

police vehicles have a smaller impact on crime in large areas versus mid-sized areas when using the *Outside Calls Ratio* and the *Outside Calls* instruments.

When instrumenting for police presence with *OCR*, I find that each additional car reduces crime by 0.116 (0.035) in the larger beats versus 0.246 (0.060) in midsize beats and 0.253 (0.075) in the smaller beats. Interestingly, this implies that a 10 percent increase in police presence in either a large beat or a mid-sized beat results in a 7.6 percent decrease in crime $\left(100 \times 0.094 \times \frac{-0.116}{0.146} \sim 100 \times 0.053 \times \frac{-0.246}{0.168}\right)$, with a smaller marginal effect of 5.7 at smaller beats $\left(100 \times 0.034 \times \frac{-0.253}{0.152}\right)$.[30] This similarity at the margin is driven by the significant difference in average police presence between beats of different size, where small beats average 20 minutes of presence, mid-sized beats average 30 minutes of presence, and large beats average 57 minutes of presence per hour. Differences in the baseline rate of police presence per beat may also contribute to the size of the deterrence effect. In other words, taking an officer away from a beat that averages little to no police presence may be more detrimental to crime control than taking an officer from a beat with relatively high levels of police presence.

The question of deterrence versus geographic displacement is an important issue. My findings suggest that increasing the size of the patrol force would decrease crime (as this could hypothetically allow an increase in police presence in all locations). However, if increasing police presence in one location simply shifts crime to the next location, it could raise significant concerns about increasing police presence in a specific beat. I therefore consider the impact of police presence at larger geographic levels in Table (8), where I would expect to find a smaller impact of police presence on crime if criminals are shifting their activities to neighboring beats. In Dallas, beats are grouped into sectors, with each sector comprised of roughly 7 beats. The measured effect of police on violent crime and burglaries at the sector level when applying the *Outside Calls Ratio* instrument

[30] When splitting the data by beat size, the first stage F tests when using the *Outside Calls* instrument are below conventional levels for small and mid-sized beats. The measured deterrence effect for large beats is larger than that of the *OCR* instrument and statistically significant at the 1 percent level.

is very similar to the estimates reported in Table (4) from analyzing deterrence at the beat level. However, when applying this same instrument, I do not find a statistically significant effect of police presence on public disturbances at the sector level. When the analysis was run at the beat level, I measure an elasticity of -.7 which is significant at the one percent level.[31] These estimates suggests that most crimes do not easily displace to neighboring areas.

5 Conclusion

While there exists an abundance of research and views regarding the deterrent effects of policing on crime, there has yet to be a detailed analysis using information on how the exact location of police officers affects behavior. In a survey conducted in May 2010, 71 percent of city officials reported decreases in the number of police personnel in order to deal with budget cuts resulting from the economic downturn.[32] With lower budgets, police departments are being forced to make tough decisions regarding police activities and deployment. Understanding how these deployment techniques impact crime is key for optimizing outcomes given the current budgets.

Police department performance measures are often a function of crime rates, arrests, response times, and clearance rates (the proportion of crimes reported that are cleared by arrests). Some deterrence programs may take time to develop and see results. Thus, a police department that is very involved in neighborhood based crime reduction activities may get little reward for its effort in terms of decreased crime rates. Additionally, as crime rates and clearance rates are influenced by outside factors and their outcomes are an imprecise reflection of investment, departments may prefer to focus

[31] The measured deterrence effects at the sector level when applying the *Outside Calls instrument* are larger than those estimated at the beat level. Thus, they do not provide any evidence of a spatial spillover effect.

[32] Information released in "The Impact of The Economic Downturn on American Police Agencies" by the US Department of Justice, October 2011.

on shortening response times, an easily measured police activity.[33] Indeed, The Dallas Morning News reported in 2013 that after criticism of rising response times to 911 calls the Dallas Police Department "temporarily reassigned dozens of officers who normally spend much of their time targeting drug activity to duties where they respond to 911 calls" (Eiserer, 2013).

The results presented in this paper raise concerns that frequently assigning officers to out of beat 911 calls may have significant costs in terms of deterring future crimes. I estimate that a 10 percent decrease in police presence at a given beat and hour increases crime at that location by 7 percent. This estimate is especially relevant to 911 calls as my instruments focus on shifts in police presence that are created because officers are assigned to incidents outside of their beat. This paper asks the question, what happens when a police car leaves its allocated area to fulfill other departmental duties? I find that shortening response times may directly impact the deterrence effect of patrol officers. This problem will only increase as the number of hired police officers decreases in size.

Despite the concern that deterrence is negatively impacted by the assignment of officers to out of beat calls, the flip side of this finding, is that the thin allocation of officers across large areas (which is driven by the rapid response philosophy) can have crime prevention benefits. The prevalent assumption that there is a tension between the rapid response philosophy and deterrence is not borne out of my research. In other words, the fact that the movement of these allocated officers impacts crime, implies that allocating officers in an effort to provide fast response times can be wedded to a deterrence policy. While the allocation of officers to beats may be driven by the demands of providing fast response times, in reality, the presence of these cars reduce the probability of crime. This may imply that police executives can "have your cake and eat it too," but does not rule out the possibility that stronger deterrence may be

[33] See Davis (2012) for a more in depth discussion regarding police outcomes and outputs (police investment).

achieved by a hotspots verus rapid response allocation strategy. Either way, my results highlight the caution that must be taken in order to maximize the deterrence benefits of a rapid response system. While arriving quickly at the scene of an incident may help to lower the expected benefit of committing a crime (see Blanes i Vidal & Kirchmaier (2017), and Mastrobuoni (2019)), it can also disrupt preemptive police activity.

My results suggest that optimizing the impact of policing on crime requires weighing the costs and benefits of assigning officers to out of beat calls. But what is the aggregate impact of outside calls on crime? If beats where 911 incidents occur gain the minutes lost at the assigned officer's patrol beat, we might expect a decrease in crime that matches the increase at the abandoned beat and no aggregate effect of outside calls on crime. However, this does not take into consideration the commuting time lost as well as the fact that an officer responding to an incident may not be as visible as an officer on general patrol. Additionally, losing an officer assigned to patrol a beat that he/she is familiar with, may have a very different effect than the added presence of a new officer in a possibly unknown environment. Indeed, recent research on increases in patrol surrounding areas where crime occurred have shown limited deterrence effects (see Vidal & Mastrobuoni (2018) and Blattman et al. (2018).

In addition to providing a measure of the crime costs of decreasing police force size throughout the US, this paper provides insight into the mechanism through which police reduce crime. My outcomes are particularly interesting given recent studies that imply that policing is only effective when focused at specific high crime locations.[34] One interpretation of my results is that police do not need to be micro managed and simply assigning them to a fairly large geographic area (beats average 1.7 square miles) will reduce crime. However, the Dallas Police Department is known to follow a directed patrol data driven strategy that attempts to direct patrol specifically to hotspot areas (street blocks with very high crime rates). Thus, within the beat, allocated police may

[34] See works by Weisburd et al. (2015) and Koper & Mayo-Wilson (2012).

be focused on specific hot spot areas that they are forced to abandon when answering a call.

This paper attempts to shed light on what police are doing in order to lower crime. My results show that their geographic presence alters crime outcomes. The next natural step is to understand how the activities of patrol officers create these crime impacts. I find that assigning officers to out of beat calls, not only reduces police presence, but also lowers arrest rates. Thus, it is plausible that part of the deterrence effect discussed in this paper is driven by an incapacitation effect, where crime decreases because a criminal is arrested before he/she can commit multiple offenses.[35] However, as this effect occurs immediately (within the same hour) it also suggests a separate deterrence channel where increased police visibility has a direct impact on crime outcomes.

[35] See work by Ater et al. (2014) that find a significant impact of arrests on crime that they attribute to an incapacitation effect.

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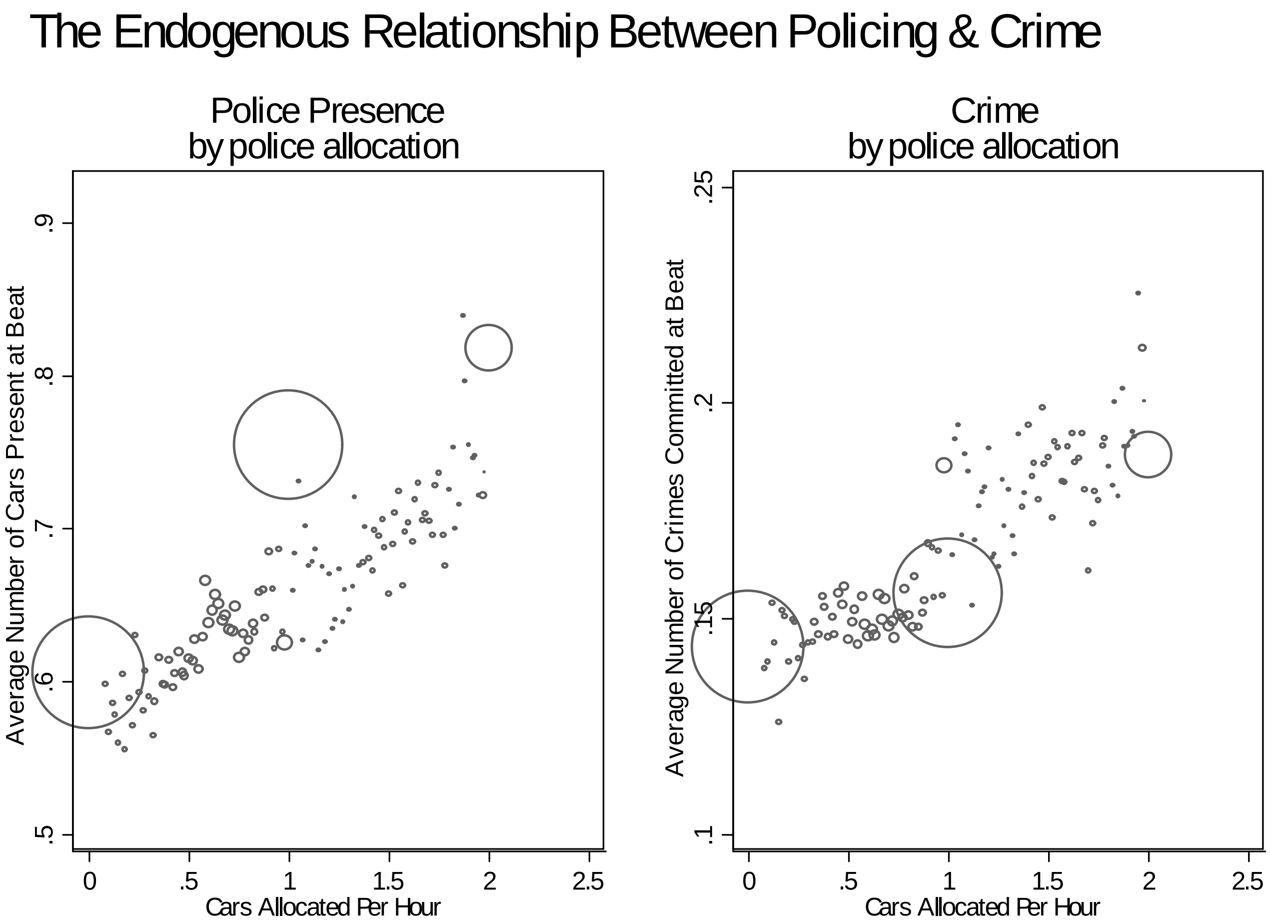
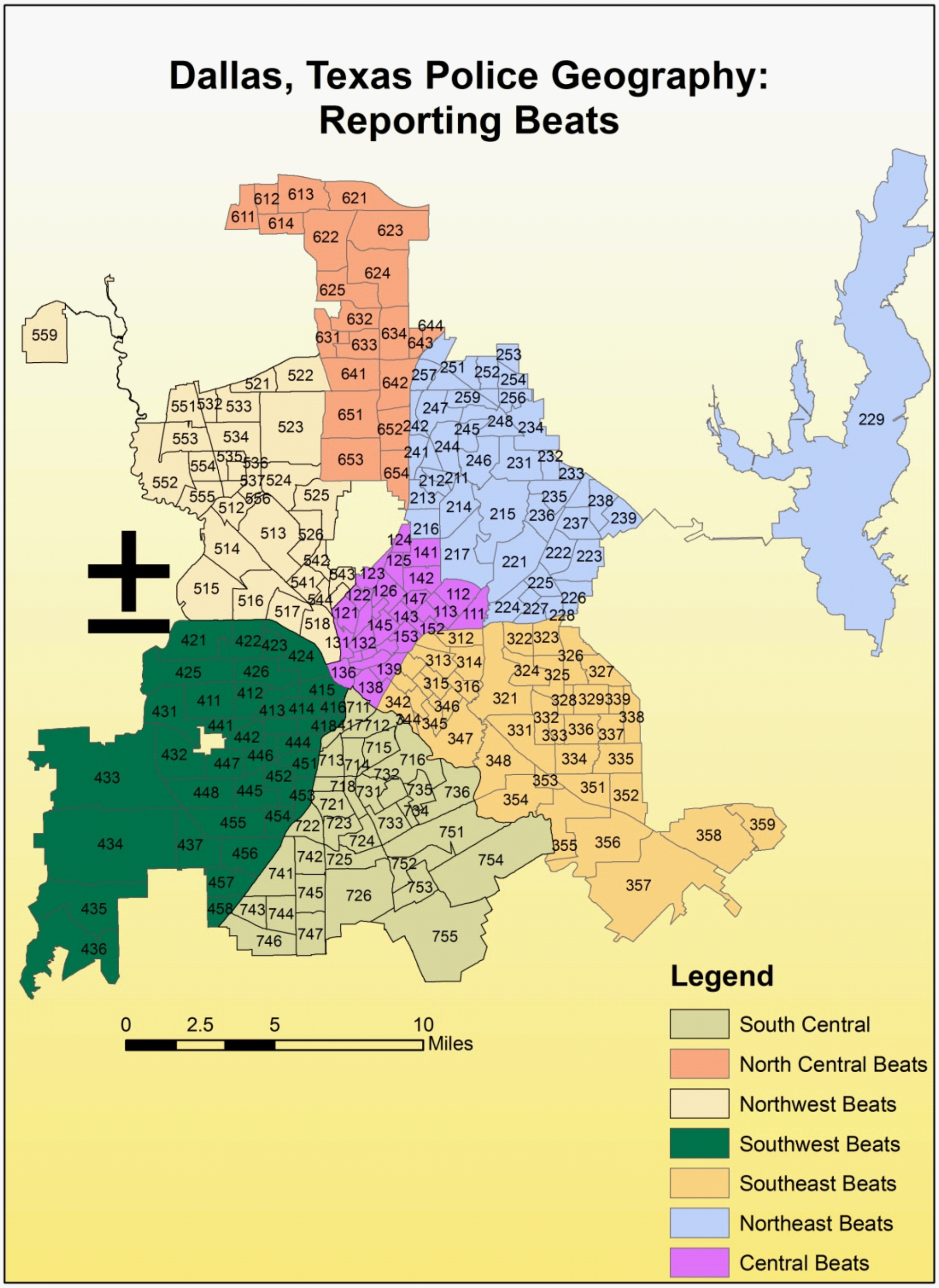


Figure 1: The data was collapsed at each vehicle allocation point. Generally either 0,1, or 2 cars are allocated to patrol a given beat at a given hour. However, if a car did not begin or end patrol on the hour this results in a fraction of car allocation. The size of the circle relates to the density of observations at that car allocation point.

Figure 2: Dallas Beats



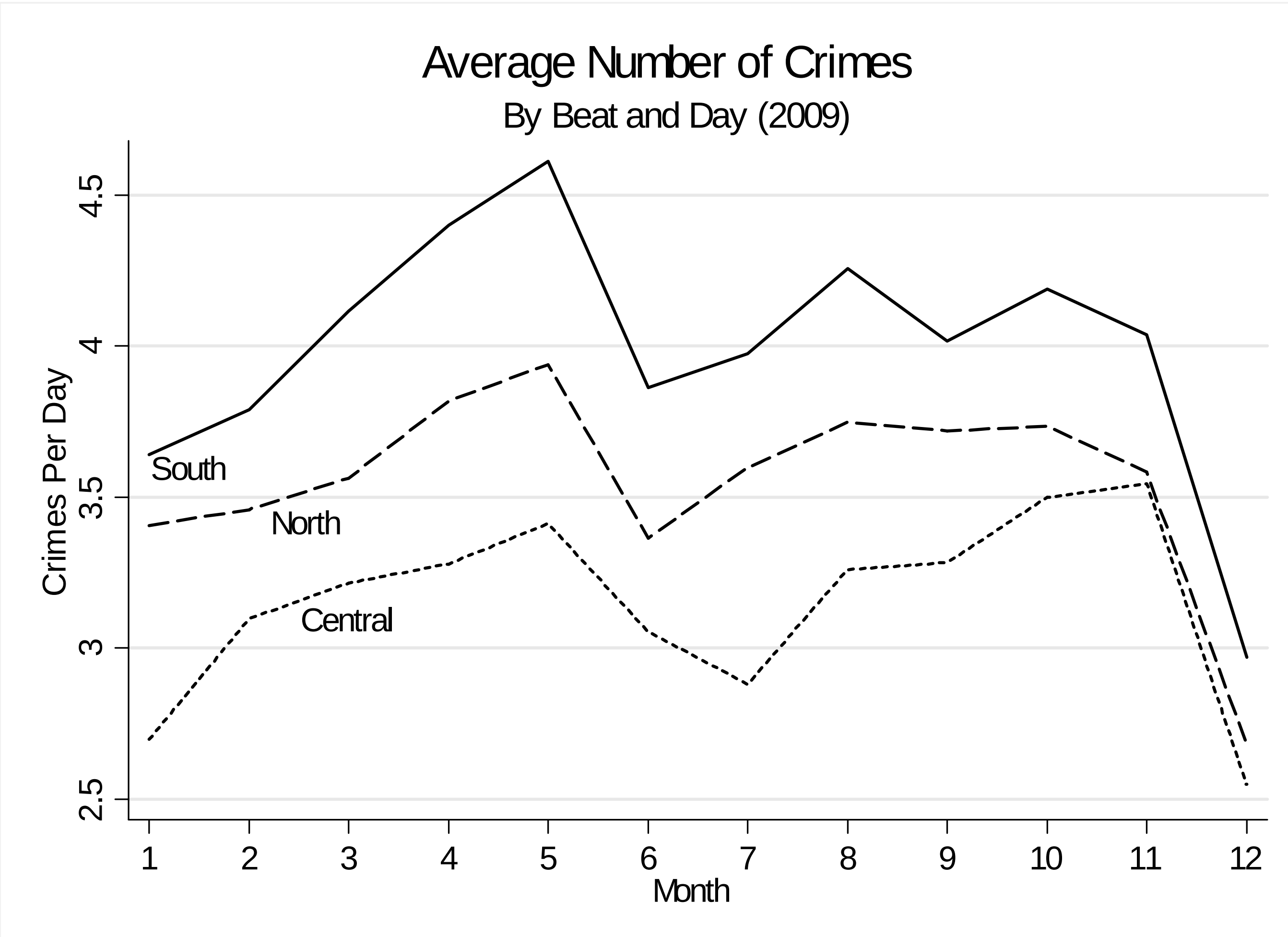


Figure 3: The data was collapsed at each beat and day of year. The South line is the average number of crimes commited per beat and day in the Southeast, Southwest, and South Central Divisions. The North line is the average number of crimes commited per beat and day in the Northeast, Northwest, and North Central Divisions.

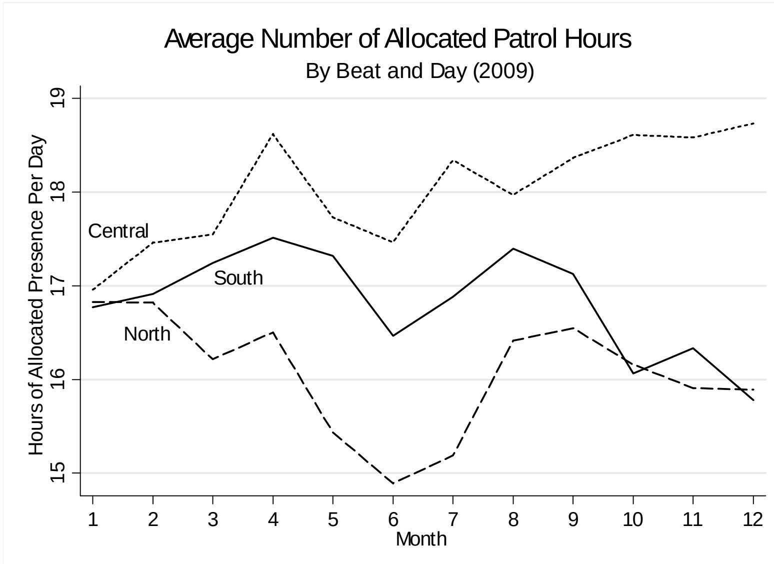


Figure 4: The data was collapsed at each beat and day of year. The South line is the average number of allocated patrol hours per beat and day in the Southeast, Southwest, and South Central Divisions. The North line is the average number of allocated patrol hours per beat and day in the Northeast, Northwest, and North Central Divisions.

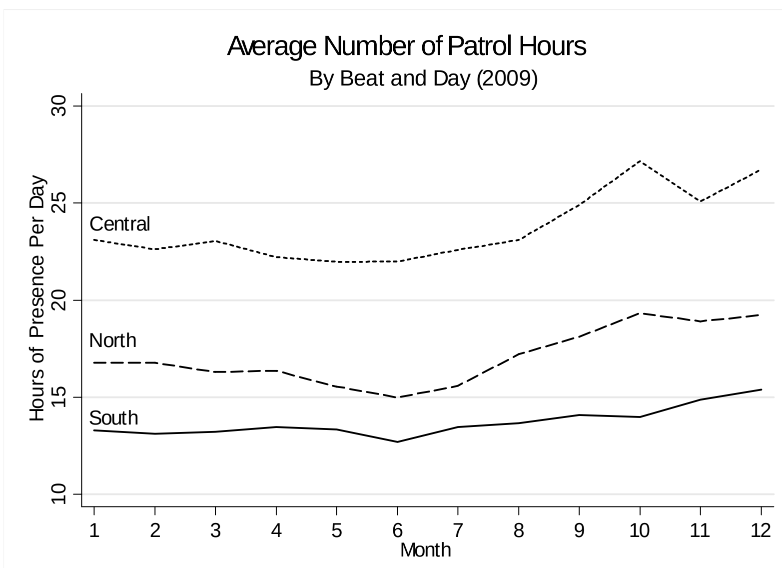


Figure 5: The data was collapsed at each beat and day of year. The South line is the average hours of actual police presence per beat and day in the Southeast, Southwest, and South Central Divisions. The North line is the average hours of actual police presence per beat and day in the Northeast, Northwest, and North Central Divisions.

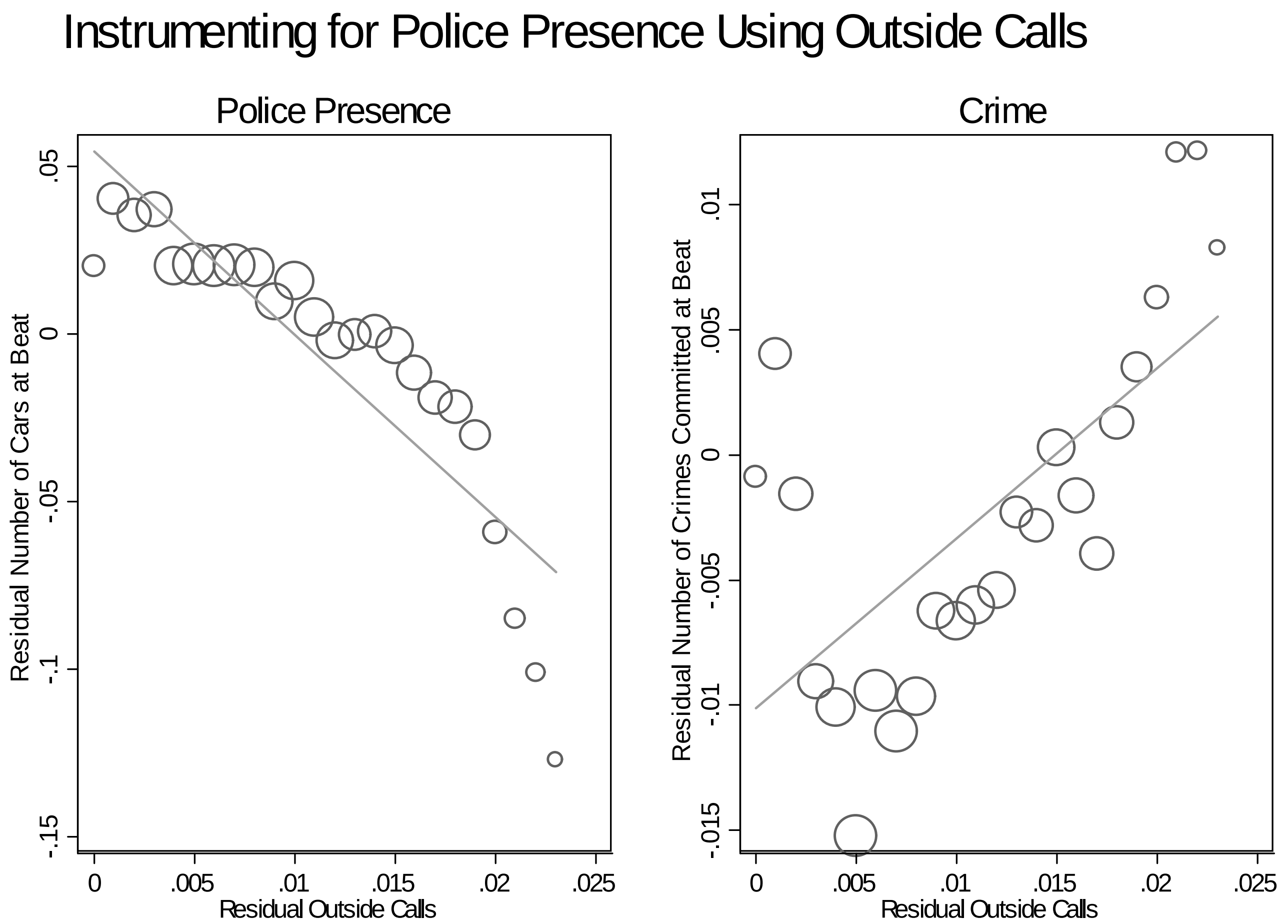


Figure 6: Residuals were calculated for police presence, crime, and outside calls by regressing each variable on weather, time of day, and date characteristics. I drop residuals that are not found across all beats or appear in less than 10 percent of the sample. The data was collapsed at each calculated Outside Calls residual point and the lowest residual of -0.025 was indexed to zero. Outside calls are defined as those reporting incidents related to mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses. The size of the circle relates to the density of observations at that residual Outside Calls point.

Table 1: Beat Characteristics Summarized by Division

Average Time Constant Beat Characteristics						Average Hourly Beat Characteristics				
Population	Road Miles	Size ($Miles^2$)	HH Income	Percent Black	Percent Hispanic	Total Crimes	Allocated Police	Police Presence	Outside Calls	Calls Ratio
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Division=Central (29 Beats)						**Division=Central (N=252,387)**				
3258.00	6.22	0.61	38409.59	0.15	0.29	0.132	0.754	0.932	0.013	0.104
(2695.87)	(3.77)	(0.32)	(13329.34)	(0.12)	(0.2)	(0.375)	(0.714)	(1.733)	(0.023)	(0.259)
Division=North Central (22 Beats)						**Division=North Central (N=191,532)**				
8613.86	9.53	1.68	75819.55	0.12	0.25	0.148	0.815	0.821	0.014	0.085
(4148.73)	(6.3)	(1.18)	(18981.49)	(0.08)	(0.21)	(0.4)	(0.607)	(1.055)	(0.027)	(0.198)
Division=Northeast (41 Beats)						**Division=Northeast (N=356,249)**				
6252.76	5.97	2.25	44423.30	0.23	0.33	0.156	0.654	0.460	0.014	0.092
(2986.75)	(3.88)	(7.22)	(14233.6)	(0.15)	(0.16)	(0.411)	(0.664)	(0.761)	(0.021)	(0.156)
Division=Northwest (31 Beats)						**Division=Northwest (N=269,700)**				
4913.36	8.97	1.52	38770.48	0.15	0.45	0.139	0.595	0.745	0.017	0.139
(3381.12)	(5.45)	(1.09)	(21082.2)	(0.16)	(0.26)	(0.385)	(0.582)	(1.229)	(0.025)	(0.263)
Division=South Central (37 Beats)						**Division=South Central (N=321,567)**				
3081.38	6.37	1.49	28069.28	0.72	0.25	0.144	0.636	0.440	0.017	0.113
(1445.97)	(5.37)	(1.6)	(8138.18)	(0.17)	(0.16)	(0.39)	(0.621)	(0.79)	(0.024)	(0.185)
Division=Southeast (39 Beats)						**Division=Southeast (N=339,378))**				
3997.67	6.32	1.63	27410.70	0.44	0.47	0.166	0.770	0.430	0.018	0.100
(1832.93)	(3.63)	(1.79)	(8372.98)	(0.27)	(0.24)	(0.423)	(0.741)	(0.782)	(0.025)	(0.196)
Division=Southwest (33 Beats)						**Division=Southwest (N=287,166)**				
5842.94	8.97	2.27	34301.05	0.26	0.62	0.194	0.702	0.615	0.021	0.129
(3087.18)	(7.3)	(3.32)	(8708.15)	(0.23)	(0.24)	(0.459)	(0.658)	(0.997)	(0.028)	(0.24)

Notes: Standard deviations are presented in parenthesis. Allocated Presence is the number of police vehicles allocated to beat per hour (60 minutes = 1 vehicle). Police presence is the number of vehicles present in beat per hour (60 minutes = 1 vehicle).

Table 2: Outside Calls as Predictors of Police Presence

	Instrument=OC Ratio[1]		Instrument=Outside Calls[2]	
	OCR	Interactions	OC	Interactions
Instrument	-0.055***		-0.078***	
	(0.003)		(0.026)	
Instrument x South Central		-0.080***		-0.687***
		(0.008)		(0.051)
Instrument x Southeast		-0.044***		-0.224***
		(0.009)		(0.050)
Instrument x Southwest		-0.044***		0.016
		(0.006)		(0.065)
Instrument x North Central		-0.070***		0.107
		(0.008)		(0.071)
Instrument x Northeast		-0.052***		-0.273***
		(0.006)		(0.053)
Instrument x Northwest		-0.055***		-0.032
		(0.006)		(0.069)
Instrument x Central		-0.052***		0.834***
		(0.009)		(0.110)
Beat Fixed Effects	Yes	Yes	Yes	Yes
Month & Day of Week FE	Yes	Yes	Yes	Yes
Weekend X Hour FE's	Yes	Yes	Yes	Yes
Observations	2,017,676	2,017,676	2,017,676	2,017,676

Notes: Each observation is a beat and hour in 2009. Standard errors in parenthesis account for geographic clustering within a 10 km radius, and serial correlation of 5 hours. Standard deviations are presented in brackets. All specifications control for temperature, precipitation, twilight, darkness, and whether or not it is a holiday.

[1]The Outside Calls Ratio is a proxy for police activity outside the beat. It is calculated by dividing the weighted sum of outside unrelated calls by the weighted sum of officers assigned to patrol the sector where the call took place. Outside unrelated calls are defined as those reporting incidents related to mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses.

[2]Outside Calls is a weighted sum of 911 calls that are unrelated to crime occurring within the division outside of the beat.

*Significant at 10%; **significant at 5%; ***significant at 1%

Table 3: The Effect of Police Presence on Crime

	OLS	IV= Outside Calls Ratio[2]	IV= Outside Calls[3]
	(1)	(2)	(3)
Police Vehicles[1]	0.012***	-0.185***	-0.181***
	(0.0004)	(0.032)	(0.054)
Temperature	0.002***	0.002***	0.002***
	(0.0001)	(0.0001)	(0.0001)
Precipitation	-0.001***	-0.001***	-0.001***
	(0.0003)	(0.0004)	(0.0004)
Twilight	0.007***	0.006***	0.006***
	(0.002)	(0.002)	(0.002)
Holiday	0.013***	-0.006	-0.006
	(0.004)	(0.006)	(0.007)
Dark	-0.00002	0.0004	0.0004
	(0.002)	(0.003)	(0.003)
Beat FE's	Yes	Yes	Yes
Month FE's	Yes	Yes	Yes
Day of Week FE's	Yes	Yes	Yes
Weekend X Hour FE's	Yes	Yes	Yes
1st Stage F Stat		321.73	40.81
Observations	2,017,676	2,017,676	2,017,676

Notes: Each observation is a beat and hour in 2009. The average crime rate is 0.15 (s.d. 0.4), average police presence is 0.605 (s.d. 1.078). Standard errors in parenthesis account for geographic clustering within a 10 km radius, and serial correlation of 5 hours.

[1]The number of police vehicles patrolling the beat at given hour (60 minutes of presence = 1 vehicle).

[2]The Outside Calls Ratio is a proxy for police activity outside the beat. It is calculated by dividing the weighted sum of outside unrelated calls by the weighted sum of officers assigned to patrol the sector where the call took place. Outside unrelated calls are defined as those reporting incidents related to mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses.

[3]Outside Calls is a weighted sum of 911 calls that are unrelated to crime occurring within the division outside of the beat. This instrument is interacted with division in order to allow out of beat calls to have different effects in different divisions.

*Significant at 10%; **significant at 5%; ***significant at 1%

Table 4: The Effect of Police Presence on Different Types of Crimes

	OLS (1)	IV= Outside Calls Ratio[2] (2)	IV= Outside Calls[3] (3)
A. Dependent Variable = Violent Crimes (mean of dependent variable 0.065, s.d. 0.258)			
Police Vehicles[1]	0.005***	-0.094***	-0.098***
	(0.0003)	(0.017)	(0.028)
B. Dependent Variable = Public Disturbances (mean of dependent variable 0.053, s.d. 0.23			
Police Vehicles[1]	0.004***	-0.061***	-0.057**
	(0.0002)	(0.017)	(0.025)
C. Dependent Variable = Burglaries (mean of dependent variable 0.032, s.d. 0.181)			
Police Vehicles[1]	0.003***	-0.030***	-0.026*
	(0.0002)	(0.011)	(0.014)
D. Dependent Variable = Theft (mean of dependent variable 0.012, s.d. 0.109)			
Police Vehicles[1]	0.001***	-0.006	0.003
	(0.0001)	(0.007)	(0.008)
Beat FE's	Yes	Yes	Yes
Month FE's	Yes	Yes	Yes
Day of Week FE's	Yes	Yes	Yes
Weekend X Hour FE's	Yes	Yes	Yes
1st Stage F Statistic		321.73	40.81
Observations	2,017,676	2,017,676	2,017,676

Notes: Each observation is a beat and hour in 2009. Average police presence is 0.605 (s.d. 1.078). Standard errors in parenthesis account for geographic clustering within a 10 km radius, and serial correlation of 5 hours. I include controls for temperature, precipitation, twilight, darkness, and whether or not it is a holiday.

[1]The number of police vehicles patrolling the beat at given hour (60 minutes of presence = 1 vehicle).

[2]The Outside Calls Ratio is a proxy for police activity outside the beat. It is calculated by dividing the weighted sum of outside unrelated calls by the weighted sum of officers assigned to patrol the sector where the call took place. Unrelated calls are defined as those reporting incidents related to mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses.

[3]Outside Calls is a weighted sum of 911 calls unrelated to crime occurring within the division outside of the beat. This instrument is interacted with division in order to allow out of beat calls to have different effects in different divisions.

*Significant at 10%; **significant at 5%; ***significant at 1%

Table 5: The Impact of Police Presence on Arrests

	IV= Outside Calls Ratio[2]	IV= Outside Calls[3]
	(2)	(4)
Police Vehicles[1]	0.025	0.079**
	(0.024)	(0.035)
Temperature	0.0003***	0.0003***
	(0.0001)	(0.0001)
Precipitation	-0.001**	-0.001**
	(0.0003)	(0.0003)
Twilight	-0.002	-0.002
	(0.002)	(0.001)
Holiday	0.00001	0.005
	(0.003)	(0.004)
Dark	-0.004**	-0.005**
	(0.002)	(0.002)
Beat FE's	Yes	Yes
Month FE's	Yes	Yes
Day of Week FE's	Yes	Yes
Weekend X Hour FE's	Yes	Yes
1st Stage F Stat	321.73	40.81
Observations	2,017,676	2,017,676

Notes: Each observation is a beat and hour in 2009. The average arrest rate is 0.03 (s.d. 0.29), average police presence is 0.605 (s.d. 1.078). Standard errors in parenthesis account for geographic clustering within a 10 km radius, and serial correlation of 5 hours.

[1]The number of police vehicles patrolling the beat at given hour (60 minutes of presence = 1 vehicle).

[2]The Outside Calls Ratio is a proxy for police activity outside the beat. It is calculated by dividing the weighted sum of outside unrelated calls by the weighted sum of officers assigned to patrol the sector where the call took place. Unrelated calls are defined as those reporting incidents related to mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses.

[3]Outside Calls is a weighted sum of unrelated 911 calls occurring within the division outside of the beat. This instrument is interacted with division in order to allow out of beat calls to have different effects in different divisions.

*Significant at 10%; **significant at 5%; ***significant at 1%

Table 6: The Effect of Police Presence on Other Types of Calls

	IV= Outside Calls Ratio[2]	IV= Outside Calls[3]
	(1)	(2)
A. Dependent Variable = Suicide Reports (mean of dependent variable 0.001, s.d. 0.037)		
Police Vehicles[1]	-0.001	-0.003
	(0.002)	(0.003)
B. Dependent Variable = Abandoned Child Reports (mean of dependent variable 0.001, s.d. 0.027)		
Police Vehicles[1]	-0.003	-0.001
	(0.002)	(0.002)
C. Dependent Variable = Fire Reports (mean of dependent variable 0.002, s.d. 0.039)		
Police Vehicles[1]	-0.001	0.0003
	(0.002)	(0.003)
D. Dependent Variable = Drug House Reports (mean of dependent variable 0.001, s.d. 0.037)		
Police Vehicles[1]	-0.001	0.005*
	(0.002)	(0.003)
E. Dependent Variable = Placebo Categories A-D (mean of dependent variable 0.005, s.d. 0.071)		
Police Vehicles[1]	-0.005	-0.002
	(0.004)	(0.006)
Beat FE's	Yes	Yes
Month FE's	Yes	Yes
Day of Week FE's	Yes	Yes
Weekend X Hour FE's	Yes	Yes
1^{st} Stage F Statistic	321.73	40.81
Observations	2,017,676	2,017,676

Notes: Each observation is a beat and hour in 2009. Average police presence is 0.605 (s.d. 1.078). Standard errors in parenthesis account for geographic clustering within a 10 km radius, and serial correlation of 5 hours. I include controls for temperature, precipitation, twilight, darkness, and whether or not it is a holiday.

[1]The number of police vehicles patrolling the beat at given hour (60 minutes of presence = 1 vehicle).

[2]The Outside Calls Ratio is a proxy for police activity outside the beat. It is calculated by dividing the weighted sum of outside unrelated calls by the weighted sum of officers assigned to patrol the sector where the call took place. Unrelated calls are defined as those reporting incidents related to mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses.

[3]Outside Calls is a weighted sum of unrelated 911 calls occurring within the division outside of the beat. This instrument is interacted with division in order to allow out of beat calls to have different effects in different divisions.

*Significant at 10%; **significant at 5%; ***significant at 1%

Table 7: The Deterrence Effect of Police on Crime by Beat Size

	IV=Outside Calls Ratio[2]			IV= Outside Calls[3]		
	Small	Medium	Large	Small	Medium	Large
	(1)	(2)	(3)	(4)	(5)	(6)
Police Vehicles[1]	-0.253***	-0.246***	-0.116***	0.047	-0.278***	-0.152***
	(0.075)	(0.060)	(0.035)	(0.078)	(0.099)	(0.046)
First Stage F Statistic	113.87	182.86	172.37	13.73	12.53	31.89
Mean Level of	0.342	0.527	0.943	0.342	0.527	0.943
Police Presence	[0.615]	[0.856]	[1.474]	[0.615]	[0.856]	[1.474]
Mean Level of Crime	0.152	0.168	0.146	0.152	0.168	0.146
	[0.404]	[0.427]	[0.395]	[0.404]	[0.427]	[0.395]
Observations	669,570	669,651	678,455	669,570	669,651	678,455
Beat FE's	Yes	Yes	Yes	Yes	Yes	Yes
Month FE's	Yes	Yes	Yes	Yes	Yes	Yes
Day of Week FE's	Yes	Yes	Yes	Yes	Yes	Yes
Weekend X Hour FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Each observation is a beat and hour in 2009. Standard errors in parenthesis account for geographic clustering within a 10 km radius, and serial correlation of 5 hours. Standard deviations are presented in brackets. All Specifications also include controls for temperature, precipitation, twilight, dark (=1 after sunset), and holiday. Small, Medium, and Large beats are defined based on the miles of roads included within the beat.

[1]The number of police vehicles patrolling the beat at given hour (60 minutes of presence = 1 vehicle).

[2]The Outside Calls Ratio is a proxy for police activity outside the beat. It is calculated by dividing the weighted sum of outside unrelated calls by the weighted sum of officers assigned to patrol the sector where the call took place. Unrelated calls are defined as those reporting incidents related to mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses.

[3]Outside Calls is a weighted sum of unrelated 911 calls occurring within the division outside of the beat. This instrument is interacted with division in order to allow out of beat calls to have different effects in different divisions.

*Significant at 10%; **significant at 5%; ***significant at 1%

Table 8: The Impact of Police Presence on Crime at the Sector Level

	IV= Outside Calls Ratio[2]	IV= Outside Calls[3]
	(1)	(3)
A. Dependent Variable = Violent Crimes (mean of dependent variable 0.428, s.d. 0.707)		
Police Vehicles[1]	-0.107***	-0.203***
	(0.026)	(0.073)
B. Dependent Variable = Public Disturbances (mean of dependent variable 0.387, s.d. 0.689)		
Police Vehicles[1]	-0.027	-0.129**
	(0.019)	(0.056)
C. Dependent Variable = Burglaries (mean of dependent variable 0.214, s.d. 0.478)		
Police Vehicles[1]	-0.035***	-0.065***
	(0.014)	(0.028)
D. Dependent Variable = Theft (mean of dependent variable 0.079, s.d. 0.284)		
Police Vehicles[1]	-0.011	-0.004
	(0.008)	(0.012)
Sector FE's	Yes	Yes
Month FE's	Yes	Yes
Day of Week FE's	Yes	Yes
Weekend X Hour FE's	Yes	Yes
1st Stage F Statistic	260.28	21.08
Observations	304,420	304,420

Notes: Each observation is a sector and hour in 2009. Average police presence is 4.014 (s.d. 3.194). Standard errors in parenthesis account for geographic clustering within a 10 km radius, and serial correlation of 5 hours. I include controls for temperature, precipitation, twilight, darkness, and whether or not it is a holiday.

[1]The number of police vehicles patrolling the sector at given hour (60 minutes of presence = 1 vehicle).

[2]The Outside Calls Ratio is a proxy for police activity outside the sector. It is calculated by dividing the weighted sum of outside unrelated calls by the weighted sum of officers assigned to patrol the sector where the call took place. Unrelated calls are defined as those reporting incidents related to mental health, child abandonment, fire, animal attacks, dead people, suicides, abandoned property, fireworks and drug houses.

[3]Outside Calls is a weighted sum of unrelated 911 calls occurring within the division outside of the sector. This instrument is interacted with division in order to allow out of beat calls to have different effects in different divisions.

*Significant at 10%; **significant at 5%; ***significant at 1%

5.1 Appendix A: The Data Cleaning Process

5.1.1 The Call Data

1. 684,584 calls recorded by DPD in Dallas, Texas in 2009

2. 556,978 calls after removing duplicate calls and hang-up calls. Calls are defined as duplicates if they are coded as duplicate or false, or if the same problem with the same priority is reported in the same reporting area (the smallest geographic unit used by DPD) within 1.2 hours of each other, or alternatively, if 2 calls are placed reporting incidents that occurred at the exact same geographic coordinates (latitude longitude points) within a 2.4 hour period.

3. 289,030 calls reporting incidents of crime: public disturbances, burglaries, violent crimes, and theft.

4. 34,783 calls that require police attention but are unrelated to crime:

Unrelated Call Type	Number of Calls	Fraction of Total Unrelated Calls
abandoned property calls	13,601	0.39
mental health calls	8,695	0.25
fire calls	3,123	0.09
drug house calls	2,856	0.08
suicide calls	2,779	0.08
child abandonment calls	1,481	0.04
animal attack calls	1,129	0.03
firework calls	1,005	0.03
dead people reports	114	0.003
Total	34,783	1

5.1.2 The Automated Vehicle Locator Data (AVL)

1. I map 91,975,620 vehicle pings of information (defined by radio name, latitude longitude points, date, and time) into DPD beats using geographic mapping software.

2. In order to differentiate between shifts for a car with the same radio name - I assign a new shift if the car has not been active for at least 2 hours.

3. Collapse data so each observation includes:

   - radio name (includes name of beat allocated to patrol)
   - beat
   - entrance time to beat
   - exit time from beat

5.1.3 The Final Dataset

1. Organized by beat, day, and hour

2. Minutes of actual presence - as defined by latitude & longitude location of police vehicles.

3. Minutes of allocated presence - as defined by radio name and patrol time.

5.2 Appendix B: Estimating the Probability of an Officer being Assigned to an Outside Call

The Automated Vehicle Locator Data (AVL) includes an indicator that matches the police vehicle to 911 incident assignments. I use this data to calculate the probability AP_{bk} that an officer from beat b is assigned to an incident in beat k. For example, if in 2009, 10 incidents occurred in beat k, 3 were assigned to an officer from beat b, 2 were assigned to an officer from beat a, and 5 were dealt with by the beat k officer, this would result in assignment probabilities $AP_{bk} = 0.3$ and $AP_{ak} = 0.2$. While these assignment probabilities can provide important information regarding the probability of assignment to an outside call, this measure could be directly affected by policing or crime in the officers allocated patrol beat. I therefore use the following procedure to define assignment weights.

Let the assignment probability (AP_{bk}) be a function of distance (d_{bk}), number of neighboring beats surrounding the patrol beat (n_b), and number of neighboring beats surrounding the incident beat (n_k),

$$AP_{bk} = \beta_0 + \beta_1 d_{bk} + \beta_2 n_b + \beta_3 n_k + \varepsilon_{bk} \tag{6}$$

Table (9) presents the estimates from equation (6). I find that officers located in beats that are 1 km farther away from the location of the incident are 13 percent less likely to be assigned to an out of beat call in that area. Sharing a border with an additional beat (thereby allowing an additional alternative for response) also lowers the probability of assignment by 4 percent.

I use the predicted values from this analysis to create a weighting factor w_{bk} that is only a function of distance between beat (b) and the beat where the incident occurred (k), as well as the number of beats that share a border with either the officer's beat (b) or incident's beat (k).

Table 9: The Effect of Distance and Number of Neighbors on Assignment Probability

	OLS (1)
Distance	-0.003***
	(0.00004)
Number of beats that share a border with (b) - officer allocation	-0.001***
	(0.0001)
Number of beats that share a border with (k) - incident location	-0.001***
	(0.0001)
Constant	0.050***
	(0.001)
R-Squared	0.30
Observations	7,796

Notes: Each observation is a match between two beats (an incident beat k and the possible patrol beat of a responding officer b). I only consider matches between beats within the same division as out of division allocation is very rare. The dependent variable assignment_probability is the fraction of calls that occurred in beat k during 2009 that were assigned to an officer in beat b. The average assignment_probability is 0.023 (s.d. 0.017), average distance between beats in the same division is 6.369 kms (s.d. 3.836).
*Significant at 10%; **significant at 5%; ***significant at 1%