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The Effect of Police Response Time on Crime Clearance Rates*

Jordi Blanes i Vidal[†] and Tom Kirchmaier[‡]

July 3, 2017

Abstract

Police agencies devote vast resources to minimising the time that it takes them to attend the scene of a crime. Despite this, the long-standing consensus is that police response time has no meaningful effect on the likelihood of catching offenders. We revisit this question using a uniquely rich dataset from the Greater Manchester Police. To identify causal effects, we use a novel strategy that exploits discontinuities in distance to the response station across locations next to each other, but on different sides of division boundaries. Contrary to previous evidence, we find large and strongly significant effects: in our preferred estimate, a 10% increase in response time leads to a 4.7 percentage points decrease in the likelihood of clearing the crime. We find stronger effects for thefts than for violent offenses, although the effects are large for every type of crime. We find suggestive evidence in support of two mechanisms: the likelihood of an immediate arrest and the likelihood that a suspect will be named by a victim or witness both increase as response time becomes faster. We argue that, under conservative assumptions, hiring an additional response officer would generate a benefit, in terms of future crime prevented, equivalent to 170% of her payroll cost.

JEL classification: D29, K40.

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Keywords: Police, Crime, Organisational Performance, Clearance Rates, Arrest Rates, Detection Rate.

1 Introduction

The likelihood that a crime is cleared and its offender charged is a central component of the standard economic model of crime (Becker 1968, Ehrlich 1973)¹. It is also critical to the incapacitation channel, by which societies can prevent hardened criminals from reoffending (Shavell, 1987). Yet, the economics literature has barely devoted any attention to studying the determinants of clearance rates in detail. While the institution with the responsibility for clearing crimes, the police, has been the focus of much recent work, most such efforts have been directed to studying its *reduced form effect* on crime. Typical approaches include examining whether police numbers (Levitt, 1997), police composition (McCrary 2007, Miller and Segal 2014) or high visibility patrolling (Di Tella and Schargrotsky 2004, Klick and Tabarrok 2005, Evans and Owens 2007 and Draca et al. 2011) are associated with lower crime rates. The implicit assumption is that a change in these variables can lead to higher chances of catching offenders, which has an immediate deterrence effect as well as an incapacitation effect over longer horizons. However, very little work has examined directly whether the police can actually increase the clearance rate with either higher numbers or, especially, with different operational practices.

A better understanding of the instruments used by police forces to apprehend criminals would allow social scientists and policy makers to make sense of the differences in crime levels and incarceration rates across jurisdictions and over time. The policy implications are also important, given that, for instance, less than a quarter of crimes are cleared in the US. Identifying which policies are most effective in increasing clearance rates could help improve them without the need for additional police resources.

In this paper we study one of the most important instruments used by police forces to apprehend criminals: responding rapidly when alerted to a crime. The effectiveness of rapid response policing seems self-evident. By arriving more quickly, police officers should be able to arrest any suspect and/or question any witness at the scene, as well as prevent

¹We use the terminology of 'crime clearance' to be consistent with the terminology in the US, where most of related studies have taken place. In the UK, police forces use the term 'crime detection'. We define 'detection' formally in Section 3. The overwhelming majority of cleared/detected crimes result in a criminal charge.

the destruction or contamination of physical evidence. Following this rationale, policing textbooks often argue that the initial response is the most important part of any criminal investigation (Hess and Hess 2012, College of Policing 2013). Rapid response has therefore long been an integral part of the toolkit used by police forces to clear crimes (Bratton and Knobler 2009, Karn 2013). In this spirit, police agencies devote vast resources to minimising response times; they track and publicise response time statistics; and they often include target response times as part of the core performance measures by which they are evaluated².

The effectiveness of rapid response policing has, however, long been questioned by criminologists. For instance, in his survey on the rise of evidence-based policing, Sherman (2013) argues:

There is no direct evidence that rapid response can make any difference in detection or crime rates and some indirect evidence that it cannot. It is very rare that rapid response can catch an offender.

Bayley (1996) is more specific:

Although many studies have sought to find it, there is no evidence that reducing the time the police take to get to crime scenes increases the chances that criminals will be caught (...). One qualification needs to be made: If police can arrive within one minute of the commission of an offense, they are more likely to catch the suspect. Any later and the chances of capture are very small, probably less than one in ten.

The notion that rapid response has no meaningful effect on crime clearance rates is one of the most well-established paradigms in the criminology literature³. Two complementary arguments are commonly put forward. Firstly, response time matters only within the first minute after a crime takes place, an unrealistically short interval for even the most

²An illustration of the first point is that the response team comprises of 24% of the total number of police officers in the Greater Manchester Police. On the second point, Appendix A displays a list of links to response time statistics among major police agencies. To demonstrate the third point, the Boston Police Department lists target average response within seven minutes for priority 1 calls as one of its three key performance indicators. Response times are also an important part of other police departments' performance goals, including Houston, Phoenix, Austin and San Diego. For an assessment of widely-used measures of police performance see Davis (2012).

³See, among others, Walker (1994), Frydl and Skogan (2004), Sullivan et al. (2004), Weisburd and Eck (2004), Cordner and Scarborough (2010), Dempsey and Forst (2011), Katz and Walker (2012) and Siegel and Worrall (2014).

efficient police organisation (Bayley, 1996). Secondly, the delay before the police are notified is typically so long that the speed of any subsequent police action becomes irrelevant (Sherman et al., 1997). The consensus among criminologists advocates a move away from rapid response policing and into other activities, such as hot spot targeting (Braga, 2001) and problem-oriented policing (Goldstein, 1990), for which there seems to be substantial evidence of effectiveness.

As we argue in detail below, existing evidence on the effect of police response time on crime clearance is far from convincing. This is unsurprising, as public-use crime-level datasets do not document police inputs, and therefore analysing response time requires the unlikely collaboration of a police department. Additionally, there is the problem of endogeneity in response time. Crimes assigned a higher priority could be those with an ex ante higher or lower clearance difficulty. Furthermore, these crimes are likely to receive more police investigative resources ex-post. As a result, identifying the causal effect of response time is a challenging exercise.

This Study We estimate the effect of police response time on crime clearance using a uniquely rich dataset and a novel research design that exploits discontinuities in response times around the boundaries of police territorial divisions. Our dataset comprises of the 2008-2014 internal records of the Greater Manchester Police, which is the second largest force in the United Kingdom and oversees a population of 2.6 million. Our dataset contains information on crime characteristics, police inputs such as response time, and police outputs such as whether the crime was cleared and, if so, how long that took. We first use OLS regressions to document a negative semi-elasticity between response time and the clearance rate.

To credibly identify causal effects, we first take advantage of a particular feature of our police force: the fact that, when a call for service is received, the responding officer often departs from the station where they are based, rather than from a random point along a patrolling route. Therefore, crime scenes closer to a response station are reached more quickly following a call for service.

Unobserved determinants of clearance difficulty at the area level might, however, correlate with distance to the response station. To account for this, we exploit the partition of the Greater Manchester territory into 11 operationally distinct divisions. This implies that crime scenes within a small local area, but on different sides of a division boundary, are

served by separate response stations, which may be at very different respective distances. In our empirical specifications we control for the 'local area' by introducing a large number of geographical cell indicators, each representing an area of .185 squared kilometres (556 metres by 332 metres). Variation in distance to the division response station, which we use as an instrument for response time, is then largely due to crime scenes in the same geographical cell falling on separate sides of division boundaries. Our identification strategy is in the spirit of Black (1999) and Doyle et al. (2015), although to the best of our knowledge we are the first to combine small geographical cells with political boundaries to take advantage of discontinuities in a *continuous* explanatory variable of interest.

We perform three separate balancing tests to confirm the identification assumption that the characteristics of a crime are uncorrelated with distance to the division response station, conditional on the geographical cell indicators. We also take advantage of the fact that some police stations do not have response teams to test the exclusion restriction that distance to a police station affects the clearance rate exclusively through the response time channel.

Findings The estimated effect of response time on the clearance rate is negative, large and strongly significant. Our preferred estimate suggests that a 10% increase in response time leads to a 4.7 percentage points decrease in the clearance rate. The 2SLS estimate is in fact much larger than its OLS counterpart, which is consistent with distance affecting response time especially for crimes for which the effect of response time on crime clearance is larger. We also find an effect on the *intensive margin*: conditional on clearing a crime, the police take less time to do so if the initial response time was faster. The effects are larger for thefts than for violent crimes, although they are also large for the latter.

As discussed above, there are several potential mechanisms through which the police could convert a faster response into a higher clearance rate. We first study whether arriving at the crime scene relatively quickly allows the police to find witnesses to the crime, question them before their recollections worsen and encourage their cooperation by signaling efficiency and dedication. There is suggestive evidence that this is indeed the case: using our baseline empirical strategy, we find that the likelihood of having a suspect named by a victim or witness decreases with response time, especially for thefts. We also find that the effect of response time on the clearance rate is larger for thefts than for violent crimes, which, as we argue below, is consistent with the 'information on suspects' mechanism being empirically

important.

We then study whether response time affects the likelihood of making an arrest immediately after reaching the crime scene. We find that this likelihood is decreasing with response time, both for thefts and for violent crimes. We interpret this as suggestive evidence that the ability to make an on-scene arrest is an important mechanism through which faster response times increase the clearance rate.

In the last section of the paper, we carry out a cost-benefit analysis of two alternative policies designed to reduce response times. We find that hiring an additional response officer would decrease response times, such that the benefit to society in terms of the future crime prevented is equivalent to 170% of her payroll cost. We also compute the maximum cost at which the policy of moving police stations to locations closer to the average crime would be cost-effective.

Related Work Our findings contradict long-held beliefs among criminologists and other social scientists regarding the effectiveness of rapid response policing. This consensus emerged as a result of the influential Kansas City Response Time Analysis Study (Pate et al. 1976, Kelling 1977). The Kansas City study examined a limited set of crimes in two neighbourhoods and throughout four months, and found no correlation between police travel time (i.e. the time between an officer being asked to attend a scene and arrival at the scene) and the likelihood of an arrest. It was then concluded that the lack of a correlation was due to the fact that it took too long for the police to be alerted (see also Spelman and Brown, 1981).

The Kansas City study suffered from significant shortcomings, including the limited and highly non-random sample; the fact that only one component of total response time (i.e. travel time) was evaluated; the fact that even this component was measured with substantial measurement error; the fact that only on-scene arrests were measured, while ignoring arrests later in time; and perhaps most importantly, the lack of any attempt to identify causal effects. In addition to the deficiencies above, the relevance of the Kansas City study for modern times is limited by the vast organisational, technological and societal changes that have occurred in the last 40 years. These shortcomings have long been acknowledged. Despite this, the matter is regarded as settled, with no study in four decades revisiting the issue. Sherman et al. (1997), for instance, argue that '*the evidence is strong*' and that, while it is non-experimental, '*there is neither empirical nor theoretical justification for such an expensive (experimental) test*'. The fact that police agencies devote vast resources to minimising

response times is regarded by criminologists as counter to evidence-based best practices.

Our paper is also related to an emerging literature in economics studying the efficiency of the police in clearing crimes. Garicano and Heaton (2010), Soares and Viveiros (2010) and Mastrobuoni (2014) all study whether the adoption of information technology by police agencies allows them to be more productive in this respect. Adda et al. (2014) show that the depenalisation of cannabis possession in a London borough allowed the police to reallocate effort and clear more non-drug related crimes.

While no study in economics has examined the relation between response time and the clearance rate, Mastrobuoni (2015) studies a related question: whether clearance rates of commercial robberies in Milan are lower around the time during which police patrols change shifts⁴. He finds that the clearance rate around these shift changes is 30% lower, and calculates that this is likely to lead to a decrease in crime through the incapacitation channel. While Mastrobuoni (2015) does not observe response time directly, a natural interpretation of his findings is that clearance rates around shift changes are lower because the police takes longer to reach the crime scene at these times.

Lastly, Weisburd (2016) uses the response of patrolling officers to incident calls outside their beat area as a source of exogenous variation to estimate the effect of police presence on crime deterrence. She shows that minimising response times has a clear cost: by deserting their beats, patrolling officers are leaving them vulnerable to opportunistic crime. Our paper complements her findings in emphasising instead the benefits of rapid response policing.

Plan We describe the institutional setting in Section 2. We introduce the data in Section 3. We describe the empirical strategy in Section 4. We present the main results of the paper in Section 5. In Section 6, we explore the potential mechanisms for these main results. In Section 7 we carry out a cost-benefit analysis of two policies designed to reduce response times. Section 8 concludes.

2 Institutional Setting

In this section, we outline some of the key features of the institutional setting in which our study takes place.

⁴An institutional peculiarity of the Milanese police is that these shift changes are likely to be particularly disruptive at regular and exogenous intervals, which allows the estimation of the causal effects of such shift changes.

Organisational Structure The Greater Manchester Police (henceforth GMP) employs approximately 6,200 officers to serve a metropolitan area with a population of 2.6 million people. Many important units such as those engaged in the investigation of organised crime are situated in the GMP central headquarters, in North Manchester. The neighbourhood patrolling and the incident response functions, however, fall under the responsibility of the 11 territorial divisions. Figure 1 displays the geographical areas served by each of the divisions. The division boundaries coincide with municipal boundaries (municipalities are called 'local authorities' or 'boroughs' in the United Kingdom) other than for the city of Manchester, which is divided into North Manchester and South Manchester⁵.

Each division has its own headquarters and a number of additional police stations from which the neighbourhood and (sometimes) the response teams operate. While the organisational structures often differ across divisions, the response and the neighbourhood teams are always operationally and hierarchically separated. Figure 2 provides a simplified version of a typical division organisational chart. The two teams are supervised by their respective chief inspectors, who in turn report to different superintendents. The lines of authority only merge at the highest level, in the figure of the chief superintendent. A consequence of this operational independence is that, when an incident call requiring either Immediate (Grade 1) or Priority (Grade 2) is received, an officer in the response team will typically be assigned to it even if a neighbourhood officer happens to be patrolling a nearby location⁶.

Call Handlers and Grade Allocation Every 999 call transferred to the GMP must be answered within a very short time by a specialised staff member, i.e. a call handler. The call handling team operates from a single central location in Manchester. Call handlers are not geographically specialised, i.e. every handler indistinctly receives calls from every area of Manchester. In answering a call, the handler questions the victim or witness, provides

⁵Our empirical strategy in Section 4 will separately identify local authority/division effects from the effect of response time.

⁶This is regarded as an efficient way to operate, for three reasons. Firstly, asking a neighbourhood officer to respond would obviously distract her from her main responsibility, i.e. patrolling. Secondly, neighbourhood officers operate mostly on foot, so it would often take longer for them to arrive at an incident scene, even if they start from a closer location. Thirdly, response officers have an array of legal powers and specialised training that other officers lack. For instance, neighbourhood officers are often PCSOs (i.e. Police Community Support Officers) without the power to arrest. Furthermore, neighbourhood officers are typically not armed with guns or tasers, while response officers often are. For Grade 1 and Grade 2 incidents a response officer will be assigned even if a patrol officer is 'right outside the house'.

advice and support if necessary, records the information received in the internal system, and assigns an opening code and a grade level.

The GMP Graded Response Policy divides calls into two categories that require the allocation of a response officer. Calls allocated a grade level 1 (Emergency Response) require the attendance of a response officer within 15 minutes of their receipt. The corresponding target for grade level 2 (Priority Response) is 60 minutes.

The allocation of a grade level to an incident call is done by taking into account two main factors: (a) whether there is a danger to someone's safety or for serious damage to property, and (b) whether evidence or witnesses are likely to be lost if attendance is delayed. The decision rule that call handlers follow in practice is relatively complex, as it involves a combination of written guidelines, unwritten but generally followed practices and their own experience. The GMP Graded Response Policy prescribes that a grade level 1 should typically be assigned when there is an imminent threat of violence or a crime in operation, while a grade level 2 is appropriate when there is no imminent threat but there may be a genuine concern for someone's safety. Calls where it is appreciated that witness or evidence is likely to be lost if attendance is delayed beyond one hour should also be allocated a Grade 2. Calls that require the attendance of an officer but where there is no threat to safety or potential loss of evidence are allocated a Grade 3 by the call handlers⁷.

Radio Operators Once the call handler has provided her input the incident becomes the responsibility of a radio operator. The radio operations team is also located centrally, but separately from the call handling team. Radio operators are geographically specialised, so when a call is received it will be the operator in charge of that area of Manchester who will be assigned to it. The radio operator uses the call handler's information, her own judgment and officer availability to assign response officers to incidents. Coordination between the radio operator in charge of a division and the local response officers is mostly direct, i.e. without involving the shift sergeant. Officers are in constant communication with the radio

⁷We will not use Grade 3 calls in our empirical analysis. The reason is that the allocation of officers to Grade 3 calls is less straightforward than the one for Grade 1 and Grade 2 calls, in ways that can potentially violate the exclusion restriction of our empirical strategy in Section 4. In particular, Grade 3 calls are often (but not always) attended by neighbourhood officers, such as PCSOs. Firstly, PCSOs may be less likely to contribute to the clearance of a case, given their limited training and legal powers. Secondly, since they are typically patrolling their local beats and therefore not based in the response stations, they may be more likely to be sent to calls located far away from these stations. These two issues suggest caution in using Grade 3 calls in a setting where distance to the response station is being used as an instrument for response time.

operators and inform them when they have reached the incident scene. The time elapsed between the call handler’s creation of the incident and the officer arrival to the scene is the response time whose effect we will be estimating.

Response Stations Response officers could in principle spend their shifts moving from one incident scene to another, without ever setting foot in the station where their team is officially based. For two reasons officers are, however, often present in the station when they are asked to respond to a call. Firstly, they may have finished dealing with an incident and, in the absence of a new call for service, reported back to the station. The second and more important reason is that, to be processed, most incidents require the inputting of information into the internal systems, which are office-based. While we do not observe in our dataset where response officers travel from on an incident-by-incident basis, we will confirm empirically that the geodesic distance between an incident scene and the closest response station (in the division to which the incident scene belongs) represents a very strong predictor of response time.

Some divisions changed the location of their response stations during our sample period. These changes led to mechanical variation in distance to the response station within a local area and across time. Needless to say, the relocation of the stations may be correlated with the evolution of crime patterns in Manchester. For example, the headquarters of the North Division relocated in 2011 to a newly developed business park, as part of an expensive urban regeneration project that included the creation of a new tram link. It is conceivable, in this example and in others, that the clearance difficulty of local crimes could have changed contemporaneously with the response station relocation. Therefore, we will be careful in Section 4 to isolate the cross-sectional variation in distance to the response station (on which our empirical strategy is based) from the potentially endogenous time variation caused by station relocations.

Response Time and the Technology of Clearing a Crime Upon arrival, response officers interrogate the victim and/or caller, question potential witnesses, undertake a preliminary investigation and report back to the radio operators. They then need to produce a report documenting the information gathered up to that point. The crime then typically becomes the responsibility of a neighbourhood officer (for less serious crimes such as thefts or assaults) or a dedicated detective (for more serious crimes such as sexual assaults or homi-

cides). The importance of the crime will obviously also determine the amount of resources that the GMP devotes to its investigation.

There are several mechanisms through which faster response time could translate into a higher clearing rate. If the crime is still ongoing, the officers could obviously apprehend the offender before he manages to flee. Even if the criminal has left the scene, a faster response may help coordinate the search for him before he has managed to get too far⁸. Secondly, the evidence could be improved when it is gathered more quickly. Physical evidence deteriorates over time, especially when located outdoors, so collecting it earlier will potentially improve its quality. Perhaps more importantly, when arriving more promptly, responding officers may be more likely to find witnesses to the crime and to interrogate them before their recollections worsen. A faster response also provides a strong signal to the victim and witnesses that the police is both competent and likely to take the offense seriously, which could improve their willingness to cooperate in the investigation.

3 Data and Descriptive Evidence

Our dataset contains every Grade 1 and Grade 2 999 call alerting the police to an ongoing or past crime in the period between April 2008 and August 2014⁹. For every call we observe among other things the location of the incident, the police response time, the UK Home Office crime classification code and an indicator of whether the crime was cleared^{10,11}.

We obtained from the GMP the locations of the police stations where the response

⁸A senior leader associated with a different police organisation confided to us that street robberies and assaults are much more likely to result in an arrest if the responding officers do a 'drive-around'. A 'drive-around' consists of obtaining the description of the assailant and circling the vicinity of the crime scene in a police car looking for individuals matching the description.

⁹Our baseline sample contains only crimes reported to the police through a 999 call. In Appendix Table A8, we expand the sample to include also crimes reported through the police radio, presumably because they were discovered by the police themselves. We impute response time to being zero for these radio-reported crimes. We find in Appendix Table A8 that the baseline estimates of the paper (in Table 4 Panel B) are very similar when we expand the sample to include these radio-reported crimes.

¹⁰Although we refer to 'crime clearance', the corresponding terminology in the UK is 'crime detection'. The official definition of 'detection' is as follows: 'A sanctioned detection occurs when (1) a notifiable offence (crime) has been committed and recorded; (2) a suspect has been identified and is aware of the detection; (3) the Crime Prosecution Service evidential test is satisfied; (4) the victim has been informed that the offence has been detected, and; (5) the suspect has been charged, reported for summons, or cautioned, been issued with a penalty notice for disorder or the offence has been taken into consideration when an offender is sentenced.' See <http://data.london.gov.uk/dataset/percentage-detected-and-sanctioned-offences-borough>.

¹¹We use the final classification code, which is assigned following the police investigation. Incidents are also given an initial ('opening') code by the handler taking the call. In case of multiple crimes occurring at the same time, an incident is given the code corresponding to the most serious one. This is known as the 'Principal Crime Rule' (Home Office, 2016).

teams were based during our sample period, for each of the 11 divisions. Each of these police stations was also the base of a neighbourhood team, in charge of patrolling a set of local areas. In addition, we were able to identify the location of other police stations that were the base of a neighbourhood team but not of a response team. We use the location of these neighbourhood non-response stations to test the exclusion restriction of our 2SLS strategy below.

Summary Statistics Table 1 Panel A provides basic summary statistics for the main variables in our study. Note first that our sample size is large, as it includes more than 300,000 crimes. Around 38% of these crimes were cleared, although this percentage varies considerably by Home Office classification code or by grade level. We can also see that the response time distribution is highly skewed, with a mean of more than one hour and a median of just 17 minutes. This skewness is confirmed in Figure 3 Panel A, where we can see that the density of the response time distribution peaks at around 5 minutes and falls concavely after that.

Around 31% of calls are allocated a Grade 1 priority level. Theft offences represent around half of all crimes (53%), and violent offences approximately a quarter (24%).

OLS Estimates Figure 4 Panel A displays a kernel regression of the clearance rate on response time¹². In addition to suggesting a negative relation, note that the shape of the relation appears strongly concave. This seems unsurprising, as every extra minute should make a bigger difference when response time is relatively fast. We will therefore use the log specification in our main regressions below, although Table 5 Panel A shows that the baseline estimates are qualitatively unchanged when measuring response time in levels.

Table 2 displays linear probability models of the crimes being cleared on (the log of) response time, accounting for an increasingly richer set of controls. Our most exhaustive specification in Column 5 controls for the hour of day, day of week, month and year in which the call was received, the division where the crime occurred, the grade level assigned by the call handler, and the Home Office-classified crime type. We find that faster response times are associated with a higher likelihood of a clearance. The estimated effect indicates that a

¹²The clearance rate variable is time-censored, since the likelihood of solving a crime increases with time. However, the overwhelming majority of crimes are cleared quite quickly, which makes this issue likely negligible in our setting. To illustrate this, 58% of clearances occur within the first week, 78% within the first month, and 96% within the first six months. We have therefore decided to ignore this potential problem in our regressions. We obtain very similar findings if we drop the last six months of 2014 from our dataset.

10 percent decrease in response time is associated with a .49 percentage points increase in the clearance rate¹³.

For several reasons we need to be cautious in giving the OLS estimates a causal interpretation. Firstly, note that the information recorded by the handler during the call will determine the priority it receives, and likely be correlated both with unobserved characteristics of the crime and with the difficulty of clearing it. Secondly, response time may be directly affected by the estimated likelihood of clearing the crime, in ways that are difficult to pin down. For instance, response time may be particularly slow when a burglar is reported to have left the scene long ago (low likelihood of clearing the crime), but also when a shoplifter has been detained by a security guard (high likelihood), since in both cases the marginal effect of a faster response may be evaluated to be low. Lastly, response time may be correlated with other policing inputs, such as the ability and attention of the responding officer. On the one hand, officers who are less competent in other dimensions of the investigation may take longer to arrive at the scene. Alternatively, it may be those officers who are aware of their low ability in other dimensions that put more effort into responding quickly. It is difficult to draw conclusions regarding the causal relation between response time and the clearance rate without a credible source of exogenous variation in the former.

4 Empirical Strategy

In this section we explain in some detail the construction of our instrument for response time. We first describe our measure of distance, discuss its potential as an instrument and explore its empirical variation. We then explain why, after controlling for a large number of small geographical cells, distance to the division response station could be regarded as a valid instrument for response time. We also discuss potential threats to the exclusion restriction.

¹³Contrary to the finding of the Kansas City Response Time Analysis Study, our OLS estimates are negative and highly statistically significant. To understand the reasons for this difference, we evaluate in Appendix Table A1 the sensitivity of our estimate to conditions closer to those of that study. In particular, (a) we discretise the measurement of response time into the three categories used there, (b) we use immediate arrests as the dependent variable, and (c) we randomly select a subsample of the same size as the Kansas City Response Time Analysis study. Our response time measure is, however, still computed with close to no measurement error, as we found no obvious way to introduce measurement error to account for the witness recollections on which the Kansas City measure is based. Separately, none of the adjustments that we perform completely eliminates the statistical significance of our estimate. Together, however, they do. The zero estimate from the Kansas City study is therefore likely the result of using data that is suboptimal on more than one dimension, including possibly the witness-recollection measurement of response time that we were unable to convincingly replicate.

In the latter part of this section, we perform tests of exogeneity of our instrument and interpret the corresponding results.

Distance and its Variation As we mentioned in Section 2, a call for service from a Greater Manchester location needs to be responded by the division response team, i.e. the team in the GMP division to which that location belongs. Our measure of distance is the geodesic, or 'as the crow flies', distance between the latitude and longitude of the crime scene and the latitude and longitude of the closest division response station. Table 1 shows that this measure is skewed to the right, with a mean of 3.2 km. and a much lower median of 2.3 km. We find in Figure 4 Panel B that the relation between response time and distance is strongly positive and approximately linear. This finding provides a validation of our claim in Section 2 that response officers often depart from the division response station when called to attend an incident. In Panel C we display a kernel regression between the clearance rate and distance. We interpret this relation as a 'naive reduced form', given our finding below that distance is not orthogonal to crime characteristics that are correlated with the clearance rate. Like the relation between the clearance rate and response time, we find it to be negative and concave.

Distance has been used as a source of exogenous variation by Reinikka and Svensson (2005), Dittmar (2011), Dube et al. (2013) and Campante et al. (2014), among others. Its validity as an instrument will obviously depend on the specific setting that is being studied. In our setting caution is warranted, since crimes in different areas may differ in terms of their clearance difficulty. This could be *by chance*. For instance, it may be that response stations tend to be located in city centres, and that crimes in these areas are easier or more difficult to clear than crimes in suburban areas. The correlation between distance to the response station and clearance difficulty could also be *by design*. In particular, it may be that police agencies choose to locate their response stations in high-crime, and perhaps high-difficulty-crime, areas, so that they can minimise response time for crimes in these areas.

Intuition of the Instrument Locations that neighbour each other but are on different sides of division boundaries are the responsibility of different response teams departing from stations that will typically be located at different respective distances¹⁴. Our instrument is

¹⁴To investigate compliance with this rule, we merged the location of all the crimes in our dataset with GMP-supplied shape files detailing the division boundaries. We then compared the division of the team that responded to a call with the division that, according to our shape files, should have officially responded.

based on the notion that, if we control with sufficient precision for the 'local area' where a crime occurs, the remaining variation in distance is mostly due to crime locations falling on different sides of division boundaries and can therefore provide a source of exogenous variation in response time.

In Figure 5, we clarify this intuition by displaying two geographical cells crossing the boundary of two divisions. As we can see, the marked hypothetical locations in Cell 3 differ significantly in the distance to their respective stations. And yet, these locations are next to each other, and crimes occurring in them should have the same average clearance difficulty.

The grid that we select for our baseline specifications covers the entire Greater Manchester Area and it contains 5,152 unique cells of .005 by .005 decimal degrees (approximately .185 squared kilometres or 556 metres by 332 metres)¹⁵. On average, around 504 people reside in each cell. For comparison, US census block groups have an average of 1,400 inhabitants. Figure 5 superimposes three realistically-sized cells on the map of Manchester and illustrates that only a handful of streets fit into a cell¹⁶.

Accounting for Division Effects One reason that the two marked locations in Figure 5 differ is, of course, that they belong to different divisions. This fact may be of concern, for two reasons. Firstly, it may be that response teams in some divisions are simply better than others at clearing crimes, and that this is correlated with the average distance to the

We found that they coincide in 99.31% of the crimes in our dataset, indicating that the official assignment rule is followed in the vast majority of cases. The remaining .69% of cases could have been associated with deviations from the official rule or, alternatively, may have been affected by measurement error in either the location variables or the division variable.

¹⁵At the latitude of Greater Manchester, a movement of .005 decimal degrees towards the equator represents a higher number of metres than an equivalent movement in the direction of the Greenwich meridian, hence the rectangular shape of our cells. We chose the number of cells with the following procedure. We first constructed a grid consisting of cells of .0005 squared degrees. We then tested whether, controlling for these cell indicators, distance was still a strong predictor of response time. If the answer was yes, we divided the cells into 2^2 sub-cells, and estimated our first stage regression with the new set of cell indicators. We continued until reaching the highest possible number of cells, consistently with a strong first stage that could be used to vary response time significantly. Our findings are robust to using a smaller or larger number of cells, although the strength of the instrument obviously decreases if we increase the number of cells beyond 5,152.

¹⁶In Table 1 Panel B, we replicate the summary statistics for the subsample of crimes occurring in the 'boundary cells' that encompass more than one division. As one would expect, crimes occurring close to the boundary of divisions are on average further away from the response station. They also have higher than average response times and a lower clearance rate. The characteristics in terms of grade and crime type are similar to those in the main sample. In Figures A3 and A4 of the Appendix, we replicate for this subsample the kernel density plots and kernel regressions of Figures 3 and 4. We draw approximately similar conclusions, with the exception of the relation between the clearance rate and distance, which appears to be much noisier. This is unsurprising, given the much reduced sample size and the fact that we are comparing crimes across (as well as within) cells, even if the cells all happen to be boundary cells.

station across divisions. For example, the response team of the (small) North Division may be differently effective at clearing crimes than its counterpart in the (large) Wigan Division (see Figure 1). Secondly, division boundaries often coincide with municipal (or, as they are called in the United Kingdom, 'local authority') boundaries. As a result, crossing a boundary could have an independent effect on the difficulty of clearing crimes if, for instance, the populations in different local authorities are affected by different types of crimes. For these two reasons, we need to ensure that any estimated effect of response time does not include the 'division effects' resulting from divisions (of potentially different size) having different types of crime or levels of policing efficiency.

Figure 5 illustrates that these division effects can be separately identified from the response time effect. For instance, because the two marked Division F locations from Cells 2 and 3 vary in the distance to their response station, the addition of geographical cell indicators and division indicators does not exhaust all the sample variation in distance. Our empirical specifications will therefore always introduce a full set of division indicators.

Estimating Equations We use a 2SLS approach to estimate the effect of response time on the clearance rate. The first stage equation between (the log of) response time and (the log of) distance for crime i occurring in year $t(i)$ in a location belonging to cell $j(i)$ and division $d(i)$ is:

$$Response_i = \alpha_0 + \alpha_1 Distance_i + Cell_{j(i)} \times Year_{t(i)} + Division_{d(i)} + \mathbf{X}_i + \epsilon_i \quad (1)$$

where \mathbf{X}_i is a vector of controls such as hour of day, day of week, month, grade level and Home Office classification code indicators.

Note that the cell indicators are interacted with a set of year indicators. The reason for this is as follows. Remember from Section 2 that the location of the response stations changed across our sample period for some GMP divisions. These changes create time variation in distance to the division station for a fixed location, even after controlling for the cell indicators. For the reasons discussed in Section 2 this time variation is potentially correlated with changes in crime patterns. We can, however, separate this time variation from our preferred cross-sectional variation based on division boundaries by interacting the cell indicators with a set of year indicators. After doing that, any variation in distance is mostly due to crimes in the same cell/year falling on different sides of division boundaries and therefore at different distances of their (fixed within a cell/year) response stations.

The second stage equation is:

$$Cleared_i = \beta_0 + \beta_1 \hat{Response}_i + Cell_{j(i)} \times Year_{t(i)} + Division_{d(i)} + \mathbf{X}_i + v_i \quad (2)$$

where $Cleared_i$ is a dummy variable that takes value one if the crime was cleared and $\hat{Response}_i$ captures the fitted values from (1).

In Appendix B we compare our empirical strategy with the strategies in studies such as Black (1999) and Doyle et al. (2015) that use boundary discontinuities for identification. In particular, we comment on the differences in approach and explain why our current strategy is well suited to the question and institutional setting of this paper.

Threats to Identification This empirical approach is subject to six main concerns. The first is the possibility that the geographical cells may not be small enough, in which case the assumption of homogeneity of locations within a cell will not be satisfied.

The second potential concern is the possibility of household sorting. For example, households concerned about crime may decide to locate themselves on the side of the division boundary with the lowest police response times, in the same way that educationally committed families have been shown to congregate in the catchment areas of good schools (Black 1999, Bayer et al. 2007).

The third concern is due to potential sorting by criminals. If sophisticated criminals target locations on the higher-distance side of a border, these locations will be associated with more crimes, and with crimes that are more difficult to solve, posing a threat to identification.

The fourth concern is more subtle, and it has to do with the mechanical effect that response time and the associated likelihood of arrest and imprisonment have on the composition of the criminal population. Namely, it may be that lower-distance locations are depleted of some of their local criminals over time, and that the remaining criminals commit crimes of higher or lower clearance difficulty¹⁷.

The fifth concern is that a lower response time may affect not only the likelihood of a clearance but also the nature of the crime itself. For instance, an immediate response may

¹⁷This is probably not a big concern, for two reasons. Firstly, it relies on criminals being extremely consistent in their location decisions, for instance by always committing their crimes at home. If instead they cross division boundaries with a positive likelihood, the differential effect on the composition of the local criminal populations on opposite sides of the boundaries will be milder. Secondly, the United Kingdom has relatively low incarceration rates, at least by U.S. standards. Differential incapacitation of criminals (and their associated effects on the composition of the local criminal populations) are therefore likely to be small.

prevent an attempted murder from becoming a murder or an assault from turning into an aggravated assault. If different crime classifications require different standards for clearance, a faster response time may be affecting the clearance rate indirectly (through its effect on the type of crime itself) as well as directly.

The last concern relates to the exclusion restriction integral to any 2SLS framework. To adequately identify the effect of response time on the clearance rate, distance to the response station must affect the clearance rate exclusively through the response time channel. The concern arises because police stations that accommodate response teams typically also contain the teams in charge of neighbourhood patrolling, and it is conceivable that crimes in areas closer to a neighbourhood station may be more likely to be cleared. For instance, these areas may on average be patrolled more intensely. Alternatively, it may be that, following spikes in crime, patrolling increases more in areas that are closer to a patrolling station, perhaps because it is easier for the leadership of the neighbourhood teams to notice increases in crime when these occur close to their base¹⁸. Lastly and most importantly, police patrols may be more likely to stop at a crime scene to hear additional witnesses and gather additional evidence if that scene is closer to the station from which they operate. This is particularly important because neighbourhood officers are in charge of following up on the investigation of the majority of crimes committed in Manchester.

In the remainder of this section, we undertake three separate balancing tests to evaluate the empirical relevance of the first five concerns outlined above. In Section 5, we exploit the fact that some patrolling stations *are not* response stations to examine the validity of the exclusion restriction. To do this, we examine whether distance to patrolling stations (that are neighbourhood non-response stations) is associated with a higher clearance rate.

Balancing Test 1: Household Demographics Our first test examines the first two concerns outlined above. In particular, we want to examine empirically whether, controlling for the cell and division indicators that are at the core of our empirical strategy, there is any evidence that households located at different distances of their respective stations differ in their demographic characteristics. To do this, we create a dataset of the 8,683 Greater Manchester output areas, the smallest geographical areas in the 2011 UK census. Using the latitude and longitude of every output area geographical centre, we assign it to a division,

¹⁸There is evidence that criminals who are not immediately arrested tend to reoffend within a few days in the same area (Mastrobuoni, 2015). Heavier patrolling following a local spike in crime might then be more likely to apprehend these repeat offenders.

and compute the distance to the 2014 closest response station. We also assign each output area to a geographical cell. We then regress distance on a set of demographic characteristics, controlling for the cell and division indicators. The estimated coefficients and confidence intervals can be found in Figure 6.

To illustrate the value of our empirical strategy, we also display the equivalent estimates and confidence intervals in a regression omitting the baseline set of cell and division indicators. We find in Figure 6 that several demographic variables appear to be statistically significant predictors of distance to the respective station at the output area level, when cell and division controls *are not* included in the regression. For example, households living further away from response stations are older, more likely to have children, and less likely to have no qualifications. Controlling for cell and division indicators has two effects. Firstly, it dramatically reduces the residual variance in the dependent variable (the adjusted R-squared jumps from .06 to .98), leading to much lower standard errors. Secondly, we observe that the estimated coefficients are now indistinguishable from zero (the F-statistic of joint significance of the demographic variables decreases from 20.4 to 1.3).

We interpret the evidence in Figure 6 as indicating that output areas within the same geographical cell contain households of similar demographic characteristics. This implies that the geographical cells that we use are sufficiently small to ensure that locations within each cell are identical in their observables, and therefore most likely in their unobservables. It also indicates that the possibility of household sorting across division borders is unlikely.

Balancing Test 2: Total Number of Crimes Our second test evaluates jointly the empirical relevance of the first five threats to identification. Every one of these hypotheses predicts that the level of crime will be correlated with distance to the response station, even after controlling for the cell and division indicators. To illustrate, consider the possibility of sorting by criminals. If some criminals are sophisticated and target locations with slow response time (including the high-distance side of division boundaries), then we should observe that locations further away from the station have more crime, both across and within geographical cells.

To study whether this is an empirically relevant issue, we create a panel dataset of census output areas and years, and compute the total number of crimes in each output area and year combination. Again, we assign each output area/year to a division and to a geographical cell. We then calculate the distance between the centre of each area and the

closest response station in that year. In Table 3, we regress one on the other, with and without controlling for the cell/year and division indicators.

Column 1 shows that areas further away from the response station are associated with less crime (the elasticity is -7.5% and strongly significant). Interestingly, this finding is inconsistent with the notion that criminals target areas with slower response time. The idea that criminals are sophisticated in their location decisions seems therefore to be contradicted by the evidence. On the other hand, a negative elasticity is consistent with the notion that the GMP choose to locate their response stations in high-crime areas¹⁹.

Importantly for the purposes of evaluating the validity of our empirical strategy, note that the estimated elasticity decreases dramatically and becomes statistically insignificant after we control for the cell/year and division indicators. We interpret the evidence in Table 3 as indicating that the first five threats to identification discussed above do not seem empirically relevant.

Balancing Test 3: Crime Characteristics All the first five threats to identification predict that, conditional on a crime occurring, the *type* of crime should be correlated with distance to the response station, even after controlling for the cell indicators. For instance, if sorting by criminals is an empirically relevant issue, we would expect it to be more prevalent among property crimes such as thefts than among violent crimes. This is because thieves are generally more sophisticated than violent criminals. Therefore, sorting by criminals predicts that crimes occurring further away from the response station should include a higher proportion of thefts, relative to violent offences.

To examine whether this is the case, we estimate the following empirical model on our baseline dataset:

$$Distance_i = \pi_0 + Cell_{j(i)} \times Year_{t(i)} + Division_{d(i)} + \mathbf{X}_i + \epsilon_i \quad (3)$$

where \mathbf{X}_i is our vector of interest, as it includes crime characteristics such as the UK Home Office crime classification code and the grade level which are strongly correlated with the clearance rate.

¹⁹An important difference between criminals and police agencies is that the latter have much better information on which to base their decisions. For instance, they observe the locations of the response stations and can experiment with them. They also have access to a large set of experience and hard data regarding the relation between response time, distance and the clearance rate. Not even the most diligent criminals can match that level of knowledge. We would therefore expect police agencies to be more sophisticated than criminals in their location decisions.

Figure 7 displays the coefficients and confidence intervals resulting from the estimation of (3), again with and without cell/year and division controls. As we can see, the classification code and grade level dummies are correlated with distance in the unconditional regression. It is interesting to note, however, that the correlations seem inconsistent with the notion that sophisticated criminals sort themselves away from the response station. In particular, theft offences are *less* numerous in locations further away from the response station, relative to violent offences.

Controlling for the cell/year indicators has the same two effects as in Figure 6. Firstly, the confidence intervals narrow significantly as a result of the decrease in the residual variance of the dependent variable (the adjusted R-squared of the regression jumps from .35 to .98). Secondly, the estimated coefficients become essentially zero, despite the much narrower confidence intervals. The F-statistic of a test of joint significance of the classification code and grade level dummies also decreases dramatically from 12 to 1.6. We interpret the evidence in Figure 7 as supporting the identification strategy in this paper.

5 Main Results

In this section we present and interpret the baseline results of the paper. We also evaluate the robustness of these results.

Baseline Estimates Before displaying our baseline estimates, we show in Panel A of Table 4 'naive IV' coefficients, based on regressions that use distance to the response station as an instrument but do not control for the cell/year indicators. We label these estimates naive based on our findings from Figures 6 and 7 and Table 3 that distance is unlikely to be (unconditionally) orthogonal to the difficulty of clearing a crime. The reduced form estimate in Column 1 suggests that crimes occurring 10% further away from the response station are .48 percentage points less likely to be solved. In the second column we find the first stage estimate. Reassuringly, the correlation between distance and response time that we first identified in Figure 4 is robust to the inclusion of time, division and crime characteristics indicators. The second stage coefficient is -.274, much larger than the OLS estimates.

We display the baseline results of the paper in Panel B of Table 4. Relative to the naive IV specification, the reduced form estimate increases slightly, from -.048 to -.065, when we introduce the cell/year controls. The first stage estimate is still very strong (the

Kleibergen-Papp F statistic for weak identification is 53), and it suggests that a 10% increase in distance to the response station is on average associated with a 1.4% increase in response time. The second stage coefficient is -.469, approximately ten times larger than the OLS estimate. The interpretation of the estimate is that a 10% increase in response time leads to a 4.7 percentage points decrease in the clearance rate.

Robustness In Table 5, we present a number of tests designed to evaluate the robustness of the baseline findings. Firstly, we introduce in Panel A response time and distance in levels (minutes and kilometres, respectively). Our earlier choice of a logarithmic form was motivated by the hypothesis that an extra minute in response time should have a bigger effect when response time is relatively fast. The logarithmic relation was also meant to capture the strongly concave relation between response time and the clearance rate plotted in Figure 4. Nevertheless, we find in Panel A qualitatively similar results when we introduce both response time and distance in levels²⁰. The second stage estimate is statistically significant at the 1% level and indicates that, on average, an extra minute in response time leads on average to a 1 percentage point decrease in the clearance rate.

In the baseline specifications we compute heteroskedasticity and autocorrelation consistent standard errors (Conley, 1999). In Table 5 Panel B we display the p-values from the wild bootstrap procedure of Cameron, Gelbach and Miller (2008), clustering at the division level. The coefficients are still significant at conventional levels²¹.

Next, we evaluate the extent to which our baseline estimates are disproportionately based on extreme values of the response time distribution. The use of the logarithmic form should minimise the impact of outliers, but the extreme positive skewness of the response time distribution (see Table 1) suggests the need for a further robustness test. Therefore, in Panel C we drop from the estimating sample observations at the top and bottom 5% of the response time distribution. Our estimates are again quite similar.

Our last two robustness tests are perhaps best understood by looking again at Figure 5. Remember that our identification strategy exploits variation in distance controlling for a large set of very small geographical cells. A large part of this variation is coming from cells

²⁰The distribution of response time has a relatively large number of outlying observations, which have a disproportionate effect on any regression in levels. Therefore, we decided to drop in this Panel observations with a response time of more than 500 minutes (this is more than 8 times the target response time for Grade 2 calls) from this regression.

²¹The results are robust to clustering at the cell, division/year and division level (Appendix Table A17).

that cross division boundaries, such as Cell 3. However, some variation in distance is also due to locations that are slightly apart from each other but in the same cell and division, such as the two locations in Cell 1. Arguably, this last type of variation is very small in magnitude, given that the cells are very small. Nevertheless, we first test the robustness of our baseline estimates to a specification that strictly uses only variation in distance across locations occurring in 'boundary cells'. To do this, we restrict in Panel D the analysis to the sub-sample of crimes in boundary cells (number of observations = 22,196). In Panel E, we adopt a less radical strategy: we keep the baseline sample while weighting every observation by (the log of) the inverse of the distance to a division boundary²². This procedure allows us to keep all the observations, while deriving our estimates disproportionately from crimes close to a boundary. Again, our estimates are very similar and we interpret this evidence as reinforcing the main conclusion of the paper²³.

Difference between the OLS and the IV estimates The 2SLS estimate is almost ten times larger in size than the OLS estimate. One possible explanation for this difference is obviously that the bias associated with the OLS estimate is positive. That would imply that crimes benefiting from faster police response are those with a lower underlying likelihood of being cleared. To understand why this relation may occur in practice, consider the likely police response when receiving a call from a victim's address. If the perpetrator of the crime also lives in that address, her identity will be known to the victim and should be eventually learned by the police, regardless of response time. If, however, the perpetrator is a stranger to the victim, the police's only chance may lie in responding rapidly in the hope of

²²Strictly speaking, we weight using the log of the inverse of distance to a boundary plus 2. Adding 2 is necessary to make all the weights positive. The logarithmic transformation is necessary to preserve the strength of the instrument. To see this last point, note Appendix Table A2, where we instead weight by the inverse of distance to a boundary. Because a very small number of crimes take place within just a few metres of the boundary, this weighting strategy leads to estimates that are strongly dependent on a very small number of observations. We find in Panel A that both the reduced form and the second stage estimate are very large in magnitude, although the Kleibergen-Papp F-statistic suggests that these estimates should be taken with extreme caution. In Panel B, we again weight by the inverse of distance to a boundary, but we drop all observations with distance to a boundary below 40 metres (approximately 1% of observations). This leads to a strong instrument and to estimates very similar to our baseline estimates.

²³In the Appendix we do an extra robustness test, motivated as follows. Given that our instrument is supposed to induce exogenous variation in response time, the estimated coefficients should not be sensitive to the inclusion or exclusion of other control variables. In Appendix Table A3, we examine whether this is the case, respectively for the reduced form and second stage estimates. We introduce sequentially the time indicators, the call handler's grade level and the Home Office classification code. The estimates appear remarkably robust to the set of controls in the regression. This is consistent with our finding in Figure 7 that distance is (conditionally) uncorrelated with these controls.

apprehending her as she flees the crime scene. Therefore, in the above example, the police will optimally take less time for the crime in which the unconditional likelihood of apprehending the criminal is lower, which will introduce a positive bias in the OLS estimation²⁴.

An alternative reason for the large magnitude of the IV estimate is that the impact of the instrument on the endogenous explanatory variable is not neutral with respect to the heterogeneity of the effect across crimes. To understand this, consider Figure 8 Panel A, where we posit a police decision-making process that is exclusively based on two characteristics of calls. The first one is whether rapid response can prevent harm to the victim and the second is whether rapid response can significantly increase the chances of clearing the crime. In Figure 8 we further assume that distance to the crime scene is negligible, but that the police pays a small cost if it responds very fast (for instance because this requires preventing the responding officer from completing her current task). We posit that under these circumstances the police would choose to respond fast unless rapid response has no effect on either potential harm or the likelihood of a clearance (i.e. for the crime at the bottom right corner).

Imagine now in Panel B that the distance between the response station and the crime scene is higher, constraining how fast the response can be. Naturally, this constraint will exclusively affect crimes where the unconstrained response was fast. Comparing Panel A and Panel B in Figure 8, we can see that crimes where distance affects response time (the 'compliers') are those characterised by a high effect of response time on the clearance rate, relative to the average crime. In other words, under this very simple police decision-making rule, the local average treatment effect should be higher than the average treatment effect.

Ideally we would want to validate this argument empirically. In practice we are unable to perfectly do that, since we cannot identify the compliant crimes. However, Figure 8 provides some guidance in this respect. Note from the figure that the compliant crimes are those for which (the unconstrained) response time is fast. Figure 8 therefore suggests investigating empirically whether the instrument affects response times mostly at the lower end of the response time distribution.

We do this in Figure 9. In Panel A we plot response time cdfs separately for low (first quartile) and high (fourth quartile) values of distance. We find that the two cdfs start

²⁴Needless to say, this stark example is provided as an illustration of a scenario that would lead to a positive bias in the OLS estimates. We do not claim that this example represents an appropriate taxonomy with which to categorise crimes.

diverging very early: most of the vertical distance between the two curves is already evident at response times of around 7 minutes. To confirm this, we plot in Panel B response time pdfs, again separately for low and high values of distance. We use the pdfs to confirm that the effect of an increase in distance is to decrease the probability of a very fast response time (i.e. below 7 minutes) and increase the probability at almost every other point of the response time distribution. Therefore, Figure 9 suggests that the main effect of an increase in distance is to prevent the police from arriving very fast *at those crime scenes that they would like to reach as fast as possible*. If, as Figure 8 hypothesises, these are precisely the crimes with a higher than average effect of response time on the clearance rate, Figure 9 provides an explanation for the large magnitude of the 2SLS estimate²⁵.

Evidence on Non-Response Patrolling Stations As we mentioned in Section 4, response stations are also the base stations from which some neighbourhood teams operate. This is a concern because it may be that it is the distance to the base station of a neighbourhood team (rather than the distance to the base station of a response team) that causes the differential likelihood of clearance that we have identified above. The main reason why this may happen is that, for the vast majority of crimes, neighbourhood officers are in charge of following up on the preliminary investigations conducted by the response officers attending a crime scene. Perhaps these subsequent investigations are somehow conducted more thoroughly when the crime scenes are closer to the neighbourhood team stations²⁶.

To examine the plausibility of this alternative channel, we take advantage of the fact that the divisions in the GMP contain a large number of police stations with a neighbourhood team *but without a response team*. We can test the validity of the exclusion restriction by examining whether distance to a neighbourhood (but non-response) station is similarly correlated with the clearance rate. We create this new measure in exactly the same way as

²⁵The analysis in Figure 9, while intuitive, is incomplete since our identification strategy uses distance as an instrument *conditionally* on cell/year and other sets of fixed effects. In Appendix Figure A5, we therefore plot the distribution of response time separately for high and low values of the residuals from a regression of (log) distance on this baseline set of controls. The difference between the cdfs is difficult to detect visually, but the pdfs confirm that the main effect of an increase in (the residuals of) distance is to decrease the probability of response times below 7 minutes. In Appendix Table A4, we display quantile regressions of log response time on log distance (Panel A) or its residuals (Panel B), at the 25th, 50th and 75th percentiles. We find that response time at the 25th percentile increases with distance at a higher rate than response time at the 75th percentile, which leads to a compression of the 75th-25th interquartile range where distance is higher. We interpret this evidence as consistent with the notion that an increase in distance disproportionately affects response times at the lower end of the response time distribution.

²⁶However, note that when we suggested this possibility to several neighbourhood officers in the GMP, the overwhelming response was that this was highly implausible.

the distance to a response station described in Section 4, and display the results in Table 6.

We first find that the effect of distance to a non-response patrolling station on the clearance rate is essentially zero. Note also that the standard errors are small, so the effect is precisely estimated. In the second column we find that response time is uncorrelated with distance to a non-response station, as we would expect. These findings suggest that proximity to a response station increases the clearance rate by decreasing response time, rather than by affecting the behaviour of the local neighbourhood team.

Effect on the Intensive Margin: Time to Clearance One way to interpret the evidence above is that response times have an effect on the *extensive margin* of the police production function, since faster response times can turn potentially non-cleared crimes into cleared crimes. We now proceed to examine whether response times also have an effect on the clearance *intensive margin*, in terms of reducing the time that it takes to clear crimes. To do this, we restrict the sample to crimes that were cleared by August 2014, and use our baseline empirical specification to study whether faster response times are associated with faster clearance times.

The second column of Table 7 Panel A shows that the estimated relation between response time and distance is very similar in the subsample of cleared crimes relative to that in the overall sample (12% versus 14%). The smaller size of the sample leads, however, to a much weaker instrument than in the baseline regressions of Table 4 Panel B (Kleibergen-Papp F-statistic of 10.54). The estimated 2SLS elasticity in Column 3 is economically large: a 10% increase in response time will lead to a 9.44% increase in the time that it takes to clear a crime (in addition to the possibility that it may never be cleared at all). If 'justice delayed is justice denied', we can think of the extra time to clearance as an additional detrimental effect of reaching a crime scene too late²⁷.

6 Mechanisms

In Section 2 we discussed potential mechanisms through which fast response time could make a difference. To reiterate, we mentioned that the police could arrest the offender

²⁷In Table 7 Panel A, our analysis is based exclusively on crimes that were eventually cleared. Instead of this, Appendix Table A9 displays the estimates from a duration analysis that includes all crimes and treats crimes that were not cleared by the end of our sample period as censored. The findings are qualitatively identical.

either at the scene of the crime or in its vicinity; they could collect physical evidence before it is contaminated or destroyed; they could interrogate witnesses before they have left the scene and they could encourage victim or witness cooperation by signaling efficiency and dedication. In this Section, we provide suggestive evidence in support of some of these mechanisms.

Information on Suspects We first study the mechanisms of witness availability and cooperation, specifically in terms of naming a suspect to the police. In our dataset, we have information on whether a suspect was named, although unfortunately we do not observe who named such a suspect or whether the suspect was confirmed as the person responsible for the crime. It seems obvious, however, that the chances of clearing a crime should improve strongly if the police receive such information. Isaacs (1967) and Chaiken et al. (1977), for instance, find that a much larger percentage of cases are cleared if the police have a named suspect. This is also the case in our dataset. Among crimes where there is a named suspect, 65% are cleared, whereas the clearance rate is only 29% in crimes without a named suspect.

To examine whether a suspect is named relatively more often when the police is faster in attending the scene, we display in Table 7 Panel B the estimates from our baseline empirical strategy where we substitute clearance by a dummy indicating whether a suspect was named to the police. We find a strong effect: a 10% increase in response time is associated with a 1.4 percentage points decrease in the likelihood of a suspect being named. This is an economically significant magnitude, given that the mean of the suspect named dummy is 24%.

Additional indirect evidence regarding the importance of this mechanism comes from differences in the effect of response time on the clearance rate across types of crimes. Victims of violent crime know their assailants in a large proportion of cases, while the same is not true for victims of theft (Uniform Crime Report, 2010). Therefore, rapid response is unlikely to have a large effect on the likelihood that a suspect is named in a violent crime. For thefts, however, reaching the crime scene quickly may be the only chance that the police has of being pointed towards the likely perpetrator. If obtaining information on suspects is a major channel through which response time matters, it should follow that the effect of response time on the clearance rate is larger for thefts than for violent crimes.

In Table 8 Panel A, we split crimes into three categories (Violent, Theft and Other) and interact the corresponding dummies with response time in equation (2) and with distance

in equation (1)²⁸. We find a much larger effect of response time on the clearance rate for thefts, relative to violent crimes, which confirms our hypothesis above and provides indirect evidence in support of the information on suspects mechanism. This larger effect is particularly remarkable since the unconditional clearance rate is actually smaller for thefts than for violent crimes.

In Table 8 Panel B, we repeat the exercise but substituting clearance by the suspect named dummy. The estimates confirm our claim that response time affects the likelihood of having a suspect named for theft crimes, but does not for violent crimes. Table 8 Panel B also establishes that suspects are named to the police much more frequently in violent crimes, most likely, as we argued earlier, due to victims knowing their assailants.

We interpret all the evidence above as suggesting that having a suspect named is a likely important mechanism through which response time affects the clearance rate, especially for thefts. Note, however, that the effect of response time on the clearance rate is still large and statistically significant for violent crimes, even though information on suspects does not appear to be an empirically important channel for such crimes. Next, we investigate an additional potential mechanism.

Immediate Arrests We now examine whether response time is related to the likelihood of making an arrest at the scene or in its vicinity. Unfortunately, our dataset does not record the location where arrests take place. We can, however, observe their timing. We create a dummy variable taking value 1 if an arrest takes place within 15 minutes of the police reaching the crime scene. While this is an imperfect measure of 'on scene arrests', we expect that most immediate arrests occur either at the scene of the crime or as the perpetrator attempts to escape. In principle, we expect all three crime types to be associated with this mechanism: reaching the crime scene more quickly could allow the police to arrest both violent criminals and non-violent shoplifters. Unsurprisingly, immediate arrests are strongly correlated with the clearance rate. Among crimes with an immediate arrest, 85% were cleared, while this percentage is only 34% for crimes without an immediate arrest.

In Table 7 Panel C, we replicate our baseline empirical strategy using immediate arrest

²⁸Alternatively, we could run (1) and (2) separately for every type of crime. Due to the large number of control indicators and to the fact that variation in distance to the response station is based on a relatively small number of observations, this strategy leads to very weak instruments. We have therefore decided to impose the assumption that the control variables do not have a differential effect by type of crime. Every result in this section must be interpreted with this caveat in mind. Note also that, to preserve the strength of the instruments, we have limited the number of crime categories to three.

as the dependent variable. We find that a 10% increase in response time decreases the likelihood of an immediate arrest by 2 percentage points, over a mean of 12%. We find in Table 8 Panel C that, as expected, this relation holds for all three crime types, although it is again stronger for thefts than for violent crimes. Nevertheless, the fact that, for violent crimes, response time affects the likelihood of an immediate arrest while having no effect on the likelihood of having a suspect named, suggests that, for violent crimes, catching the offender at the scene may be the most important mechanism.

Needless to say, the evidence in this section does not represent *conclusive* proof that immediate arrests (or, for that matter, information on suspects) are a channel through which response time affects the clearance rate. It may be that every case with an immediate arrest would have been solved eventually, even if the police had not made such an arrest. This would be the case, for instance, if the victim knows her aggressor and additional necessary evidence does not deteriorate over time. We interpret the evidence here as *suggestive*, but not conclusive of the notion, that immediate arrests may be a channel through which response time matters.

7 Cost-Benefit Analysis

We now perform a cost-benefit analysis of two hypothetical policies introduced in 2014 and engineered to reduce average response times: (1) hiring one additional response officer, and (2) moving the response stations to alternative, optimally chosen, locations. We concentrate on the benefits arising from the crimes prevented when the clearance rate is higher, and ignore other benefits such as those arising from restorative justice or 'cold glow' effects (Ouss and Peysakhovich, 2015). Catching more criminals prevents more crimes through two main channels: it discourages potential criminals from offending (deterrence) and it prevents offenders from re-offending (incapacitation). We consider these two channels separately because incapacitation requires prosecuting and incarcerating criminals and is in this respect an expensive tool, relative to deterrence. We devote the first two subsections to outline the methodology and assumptions underlying the calculation of the effects. In the last two subsections we use this methodology to compute the net benefits of the two posited policies.

Benefits and Costs from Incapacitation Assume a one percentage point increase in the clearance rate in 2014. Given that 17,550 crimes occurred in 2014, this would have

resulted in 175.5 additional cleared crimes. Appendix Table A10 calculates the additional years of incarceration following this increase. We account for the fact that only a fraction of cleared crimes lead to a criminal charge and that only a fraction of prosecuted crimes lead to a conviction. Because the UK criminal justice system is relatively lenient, as compared to its US counterpart, only a small fraction of convicted offenders are incarcerated and, conditional on incarceration, average custodial sentences are relatively short. Lastly, we account for the fact that the transitions between different stages of the criminal justice system vary greatly across crime types. To illustrate, robberies comprise only a small proportion of GMP crimes but lead to a high number of additional years of incarceration, while the opposite is true for criminal damage crimes. In total, we calculate that this increase in the clearance rate would lead to an extra 17.85 years of incarceration.

The benefit of an additional incarceration year depends on the effectiveness of incarceration in decreasing crime and on the social cost of the crime prevented. Buonanno and Raphael (2013) and Barbarino and Mastrobuoni (2014) provide the best estimates of the number of crimes prevented per year of incarceration, and we use their middle point estimate of 18 crimes^{29,30}. Studies measuring the social cost of crime have used a wide variety of methods (Donohue, 2009). We use the estimates from Home Office Report 30/05 because they are UK-based and quite comprehensive, including costs in anticipation of crime (e.g. protection and insurance), and costs resulting from the actual crime committed (e.g. harm, lost output and criminal justice costs). The average cost per crime is £4,189 (Appendix

²⁹Buonanno and Raphael (2013) estimates are 13 and 18, depending on the specification. Barbarino and Mastrobuoni (2014) baseline estimate is 23. These two papers use the same natural experiment in Italy and generate estimates that are both highly credible and likely applicable to a UK context. Note importantly that the estimates are inclusive of general equilibrium effects. Vollaard (2013) uses a similar policy experiment from the Netherlands and estimates the number of crimes avoided to be 60. We do not use this much higher estimate because, unlike in Italy, the Dutch experiment targeted prolific offenders. If the crime-reducing effects of additional incarceration are subject to diminishing returns as less crime-prone individuals are incapacitated (Vollaard 2013, Buonanno and Raphael 2013), the estimates from the Italian experiment are more appropriate. We also do not use the lower estimates of Owens (2009) and Johnson and Raphael (2012) for the very similar reason that they are generated from the US criminal justice system, which is characterised by an incarceration rate of 666 per 100,000 (Institute for Criminal Policy Research, 2016). This is much higher than the 146 of England and Wales or the 91 of Italy, again prompting the concern of diminishing returns. We do not use earlier evidence on incapacitation effects because it typically suffers from weak research designs or insufficient statistical power and is also generated in a US context (Marvell and Moody 1994, Levitt 1996).

³⁰Note that we do not differentiate between the types of crimes being prevented, therefore implicitly assuming that these are proportional to the prevalence of these types in the population of total crimes. We would expect the population of incarcerated criminals to contain relatively serious offenders. To the extent that criminals specialise in one type of crime, it should be the relatively more serious crimes that are prevented by incapacitation.

Table A11). This cost is well below most estimates in the literature so we view it as highly conservative³¹.

Preventing crimes through incapacitation has costs, however. The cost per incarceration year is £33,785 (UK Ministry of Justice, 2014). Appendix Table A12 calculates the criminal justice costs from the prosecutions that result from increasing the clearance rate by one percentage point, which we also base on the figures of Home Office Report 30/05³².

Benefits from Deterrence Most credible empirical research on deterrence has adopted a reduced-form approach, linking crime to the number and visibility of police officers rather than to the likelihood of being arrested and prosecuted (Chalfin and McCrary, 2017). The relatively few studies estimating the effect of clearance rates use panels of states or cities, and often suffer from measurement error and endogeneity biases. The most influential study is probably Levitt (1998), who finds elasticities between -.1 and -.3 for five crime categories and interprets these as mostly reflecting deterrence, rather than incapacitation³³.

In Appendix Table A13 we provide an estimate of the deterrence benefit of increasing the clearance rate by one percentage point. Due to the lack of precise and credible estimates in the deterrence literature, we are highly conservative in our assumptions. Firstly, we assume an elasticity of -.1, which is at the very lowest end of the range of values typically estimated. Secondly, we assume that this non-zero elasticity only applies to robberies, thefts and violent crimes, therefore assuming no deterrence at all on a quarter of Manchester crimes including some serious crimes such as sexual assaults. Thirdly, we measure the social cost of crime again using the Home Office Report 30/05, a conservative estimate. Overall, we estimate a benefit of £138,240 resulting from this assumed increase in the clearance rate.

³¹For example, our cost is much lower than influential estimates such as Cohen et al. (2004), McCollister et al. (2010) and Cohen and Piquero (2009), and slightly below the estimates in Barbarino and Mastrobuoni (2014).

³²There are other costs that, while potentially important, are difficult to quantify. For instance, we do not account for the incarcerated individual's wasted human capital, the potentially increased criminal capital, the decline in wages following her release and the pain and suffering of inmates and their families. For a discussion of the difficulty in measuring these, see Barbarino and Mastrobuoni (2014).

³³The categories are aggravated assault, robbery, burglary, larceny and auto theft. The standard errors are very large for homicide and rape, due to insufficient statistical power (see Table 3 in Levitt 1998). Other recent studies include Mustard (2003, elasticities ranging from -.1 to -.3), Kelaher et al. (2016, elasticities ranging from -.25 for property crimes to -.33 for violent crimes), and Curry et al. (2016, elasticities from -.2 to -.4 for violent crimes and from -.5 to -.6 for property crimes.). Again, these elasticities are typically interpreted as mostly reflecting deterrence. We account for the fact that they may also partly capture incapacitation effects by being highly conservative in the elasticity that we use in our computations.

Hypothetical Policy 1: Hiring One Additional Response Officer We now evaluate the hypothetical policy of hiring one additional response officer in 2014. The annual total cost of the officer is £45,745, including salary, training, benefits and pension contributions³⁴. Obtaining a causal estimate of how this additional officer will affect response times is not straightforward. A plausible estimate can be obtained by exploiting variation in the number of response officers that are unavailable due to sickness, under the assumption that variation in this measure is idiosyncratic conditionally on the baseline set of controls³⁵. In Appendix Table A14 we regress response time on the number of sick police officers, using different parametric specifications. The most conservative estimate suggests that an increase by one unit in the number of response officers available reduces response time by .22%.

Putting together the above figure with the baseline estimate from Table 4, we predict an increase in the clearance rate of .001045 percentage points³⁶. Using the methodologies in Appendix Tables A10-A13, we can then compute the predicted additional years of incarceration and the benefits and costs through the incapacitation and deterrence channels. In Table 9 Panel A we add these costs and benefits to calculate the interim benefit of the policy (£77,851). We find that hiring an additional officer would generate a benefit equivalent to 170% of her payroll cost.

Needless to say, the finding that the net benefit of this policy is positive and large is a direct result of this paper’s baseline result that reducing response times leads to a large increase in the clearance rate. In addition, two elements are important. Firstly the fact that, according to the best available estimates, incapacitation effects are substantial

³⁴This annual cost is calculated on the basis of the estimate of £47,000 provided in 2017 to us by the GMP. Compensating the officer and incarcerating criminals would in principle require raising taxes. We do not account for the resulting tax distortions in our calculations.

³⁵The sickness data was provided by the GMP Human Resources department and it captures the dates in which officers were officially sick, regardless of whether they were on duty on that particular date. Unfortunately, we do not have information on the rotas of the response teams. A potential concern arises if officers strategically report sick only on days when they are on duty. If that is the case, a regression of response time on the number of sick officers will overestimate the effect of hiring an additional officer. This is because this additional officer would only work a 40-hour week, which includes duty and non-duty days. An additional related concern is that the disruption to a response team may be particularly high if an officer calls in sick shortly before the shift is about to start. In practice, the number of days lost to very short sickness spells (three days or less) is very small, making strategic or last-minute reporting a minor concern. An additional concern is that officers that typically fall sick may be of lower quality, in which case their absence may not have a representative effect on response time.

³⁶An assumption here that we make for simplicity is that response time increases the clearance rate equally for all crime types. Appendix Table A10 shows that incarceration for thefts and robberies account for a very large proportion of the total incarcerated years. Allowing response time to affect clearance rates differently using the estimates from Table 8 would increase the theft and robbery incarcerated years and therefore the incapacitation effects.

(and incarceration levels well below optimal)³⁷. Secondly, we have relied on the finding in Appendix Table A14 that response times in Manchester appear to be highly constrained by the availability of personnel³⁸.

Hypothetical Policy 2: Relocation of Response Stations We now evaluate the alternative policy of reducing the distance between the average crime and the closest response station. To the extent that the location of response stations in 2014 was not optimal, relocating to new premises could substantially reduce response times and increase clearance rates. We assume that suitable buildings could be found in the alternative optimal locations, and calculate the maximum relocation costs that would make such moves worthwhile.

Any optimality procedure must account for the fact that divisions often contain more than one response station, so the optimal location decisions require identifying from what station each crime will be responded. We use the clustering algorithm K-means, which finds geographic concentrations in a point database and determines the center points. After identifying a cluster partition, the process continues iteratively until all points are associated with the closest mean center. We set the number of clusters in each division equal to the number of response stations in 2014.

Appendix Table A15 displays the results of this procedure, separately for each division. As expected, the average distance is always lower when we relocate response stations to their optimal locations. We use the baseline estimates from Table 4, together with the methodologies in Appendix Tables A10-A13, to calculate the predicted increase in clearance rates and the benefits through the deterrence and incapacitation channels. Because a station relocation costs a lot upfront but yields benefits over a long horizon, we compute the overall benefits over the following ten years³⁹. We then calculate the relocation cost per station that

³⁷On the other hand, given the uncertainty in the literature we have avoided assuming large deterrence effects. Because deterrence effects are probably larger than we have assumed, the net benefit in Table 9 can best be interpreted as a lower bound estimate.

³⁸The importance of this constraint has been repeatedly expressed in public by GMP officials (Storey 2014, Scapens 2016), and is consistent with the large reductions in the number of police officers following the budgetary cuts that started in 2010.

³⁹This aggregation requires two important assumptions. Firstly, that the average locations where crimes occur are unchanged over time, making the new locations optimal throughout the ten year period. Implicit in this assumption is the notion that criminals do not observe the station relocations, understand the importance of response times, and adjust the location of their crimes accordingly. This notion is consistent with the evidence in Table 3 and Figure 7 on the absence of discontinuities in crime rates and types around division boundaries. However, it may still be that the presence of a nearby response station is easily observed and responded to at least by criminals operating in its close vicinity. The second assumption is of a zero discount rate. This is for simplicity, and the calculations can be easily adjusted to account for a positive discount.

would allow this policy to break even over ten years. Appendix Table A15 orders the divisions from higher to lower break-even cost, and shows that there is substantial heterogeneity in the cost effectiveness of the policy. In the South division, for instance, relocating the three response stations would reduce the average distance by 44%, so the policy would be worthwhile even if each relocation costs almost a million pounds. In Bury, on the other hand, the existing response stations are almost optimally placed, making the cost-effectiveness of this policy much lower⁴⁰.

In Table 9 Panel B we compute the benefits of relocating *all* the response stations in Manchester. We find that this policy would be cost effective as long as, on average, it costs less than £369,814 to relocate a response station.

8 Conclusion

In this paper we have provided robust evidence of a causal effect of police response time on crime clearance rates. The estimated effects are large and strongly significant. They hold on the extensive margin (clearance rate) as well as on the intensive margin (time to clearance, conditional on eventual clearance). We find stronger effects for thefts than for violent offenses, although the effects are large for every type of crime. Lastly, we have provided some evidence on two of the mechanisms through which police response time operates: the likelihood that a victim or witness will name a suspect to the police, and the likelihood of making an 'on scene' arrest.

Our findings contradict long-standing beliefs among criminologists regarding the effectiveness of rapid response policing. While the existing consensus is that rapid response policing has either a zero or at best a very weak effect on the clearance rate, we argue that minimising response time is a highly effective policy in terms of apprehending a larger

We note, however, that during this period interest rates in the UK were close to zero.

⁴⁰It is difficult to obtain precise information on the likely cost of relocating a police station. A particular complicating factor is that often response teams share the premises with other police units, such as neighbourhood or investigative teams. As a result, the buildings where they are based have areas larger than the minimum areas required to house only a response team. In Appendix Table A16, we provide information on all the GMP ex-police station buildings that were sold at auction between 2007 and 2017. Together with the sale price, we have information on the building area and on whether that building was the base of a response team at some point in the past. Buildings that housed a response team are clearly bigger and more expensive. Even under the most conservative assumptions Appendix Table A16 reveals, however, that the relocation policy would be cost effective for at least some divisions. For instance, assuming a relocation cost equal to a 10% of the building's value and using as a reference point the most expensive building in Appendix Table A16 (Bootle Street, £2.5 million), the relocation policy would be worth pursuing for five of the eleven GMP divisions.

percentage of criminals. This is clearly critical for societies interested in providing general deterrence or in incapacitating criminals that are unlikely to be deterred.

Needless to say, we do not claim that financial resources should be allocated to this particular policy and in detriment to every other policy that could help combat crime. Nevertheless, we have identified two policies that under reasonable assumptions would be more than cost effective from a societal perspective.

Lastly, as Sherman (1997) indicates, one reason for the failure to question the above consensus with new work is that field experiments on response policing are both expensive and ethically challenging. This paper illustrates the potential for using natural variation in policing inputs to study the effectiveness of policing practices, in settings where experimental variation is unfeasible.

FIGURES

Figure 1: Map of Manchester Divisions



Figure 2: Typical Division Organisational Structure

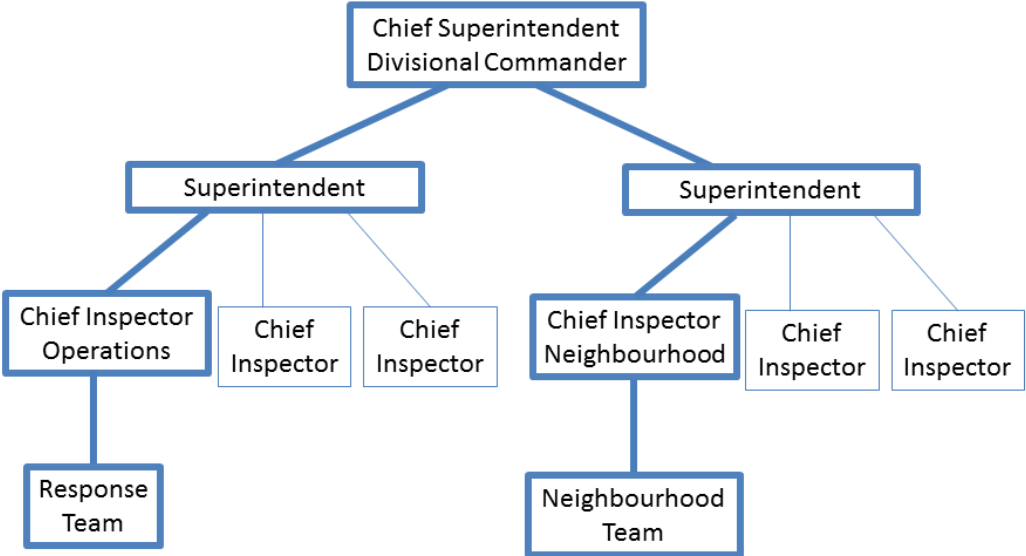


FIGURE 3: KERNEL DENSITIES

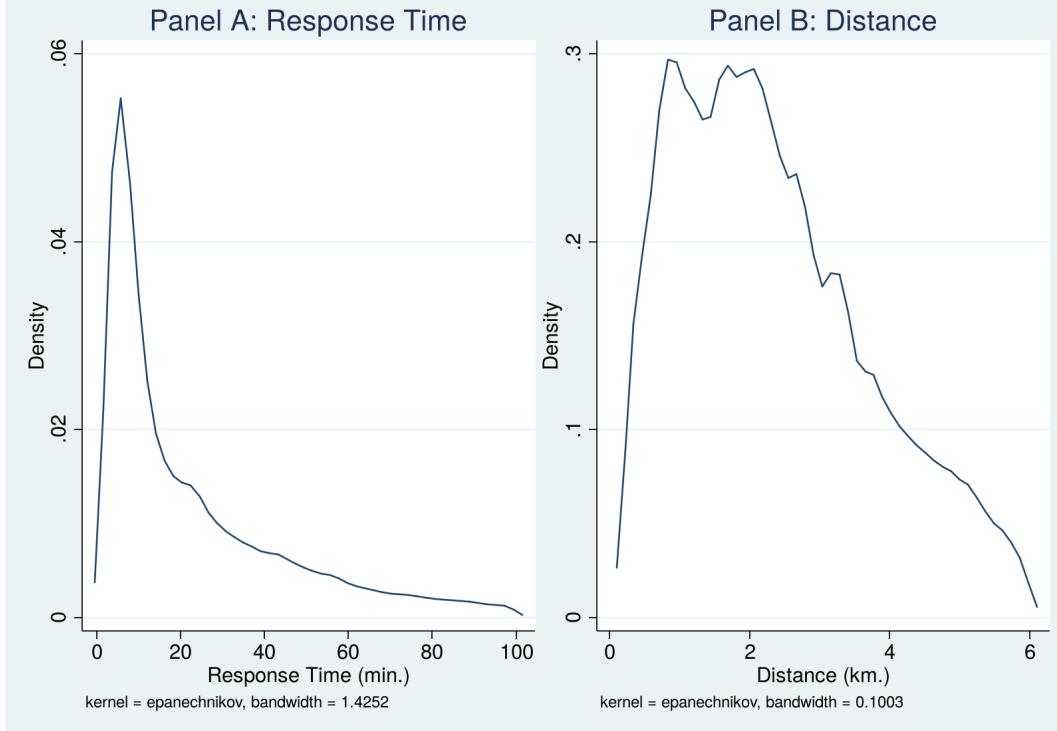


FIGURE 4: KERNEL REGRESSIONS

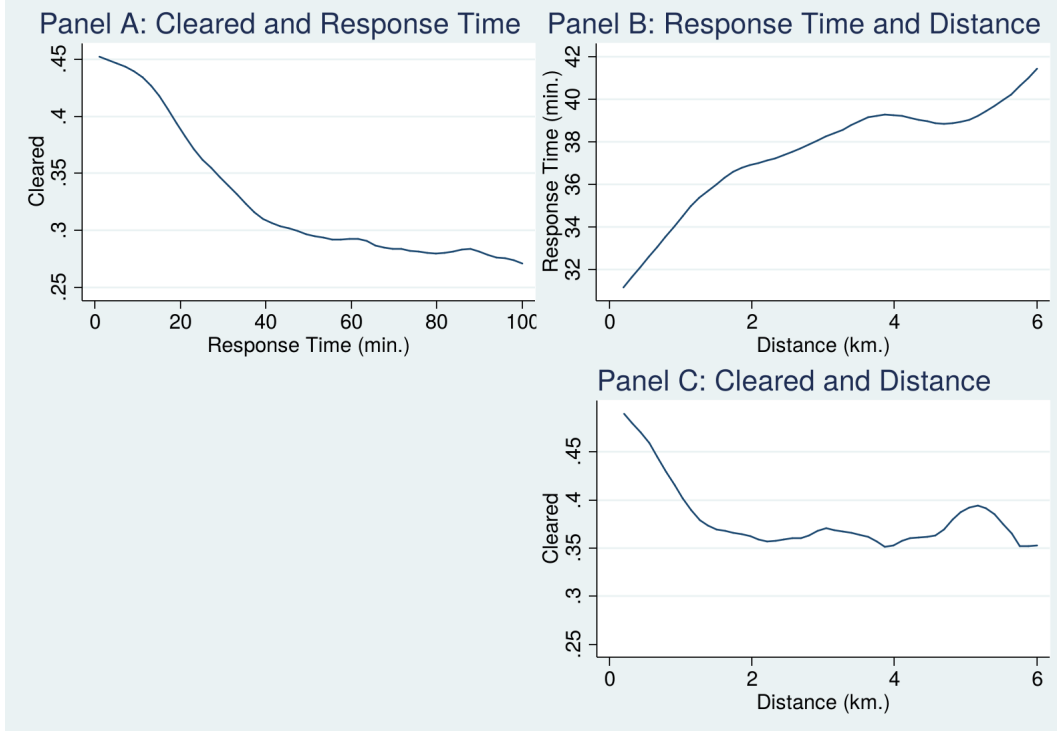


Figure 5: Illustrating Empirical Strategy

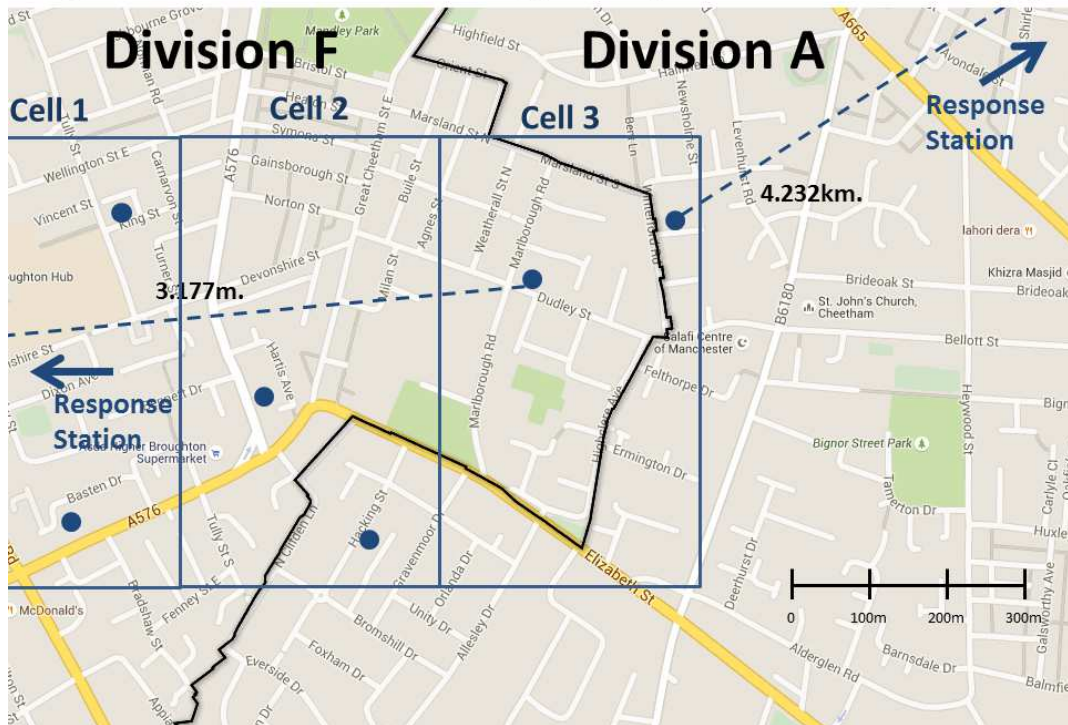
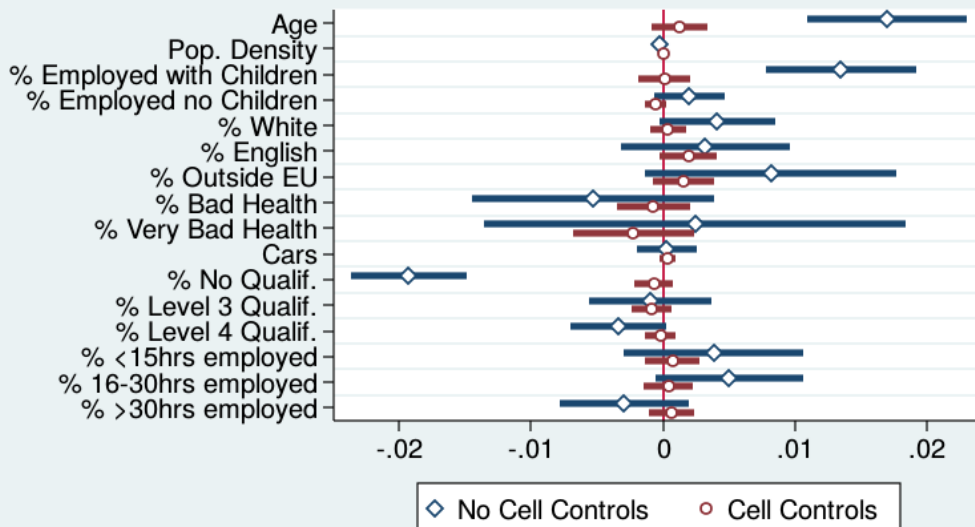
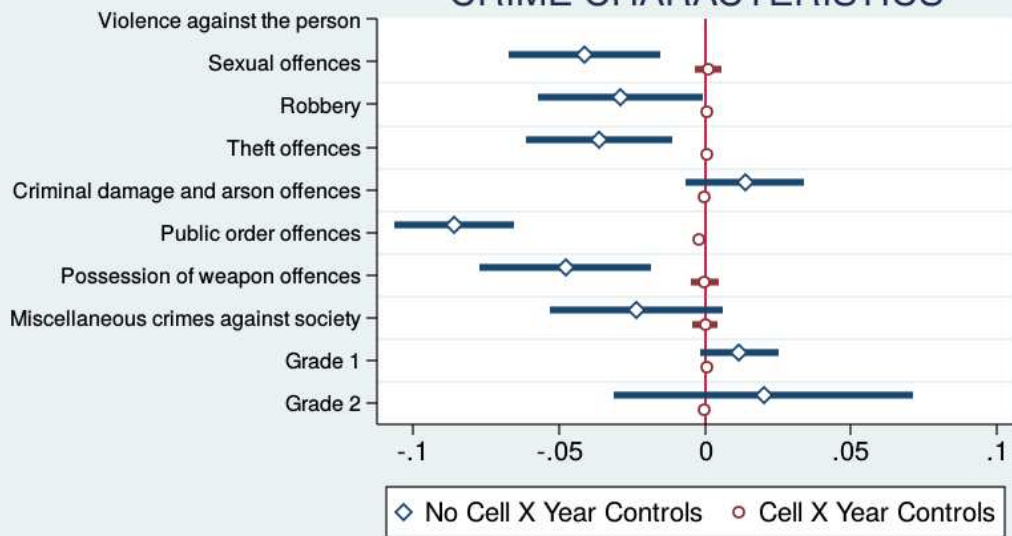


FIGURE 6: BALANCING TEST 1 HOUSEHOLD DEMOGRAPHICS



This Figure displays the estimated coefficients and confidence intervals of two separate regressions. An observation is a 2011 UK census Greater Manchester output area. The number of observations is 8,683. The dependent variable is Log Distance. The independent variables are displayed in the vertical axis. Standard errors clustered at the Cell level in both regressions. The F-statistic of joint significance of the independent variables is 20.4 for the regression without cell indicators and 1.3 for the regression with cell indicators.

FIGURE 7: BALANCING TEST 3
CRIME CHARACTERISTICS



This Figure displays the estimated coefficient and confidence intervals of two separate regressions. We use the baseline dataset of crimes between April 2008 and August 2014. The number of observations is 306606. The dependent variable is Log Distance. The independent variables are displayed in the vertical axis. Violence Against the Person and Grade 2 are the Omitted Groups for the Home Office Code and Grade Categories, respectively. Both regressions control for Division and Hour of Day. Heteroskedasticity and autocorrelation consistent spatial standard errors in parentheses (Conley, 1999). The cross-sectional units are the cells (cutoff = 10km.) and the time units are the years (two lags). The F-statistic of joint significance of the independent variables is 12 for the regression without cell indicators and 1.5 for the regression with cell indicators.

FIGURE 8: HYPOTHETICAL RESPONSE TIMES, BY CRIME TYPE
ILLUSTRATING THE DIFFERENCE BETWEEN LATE AND ATE

Panel A: Response when Distance Low

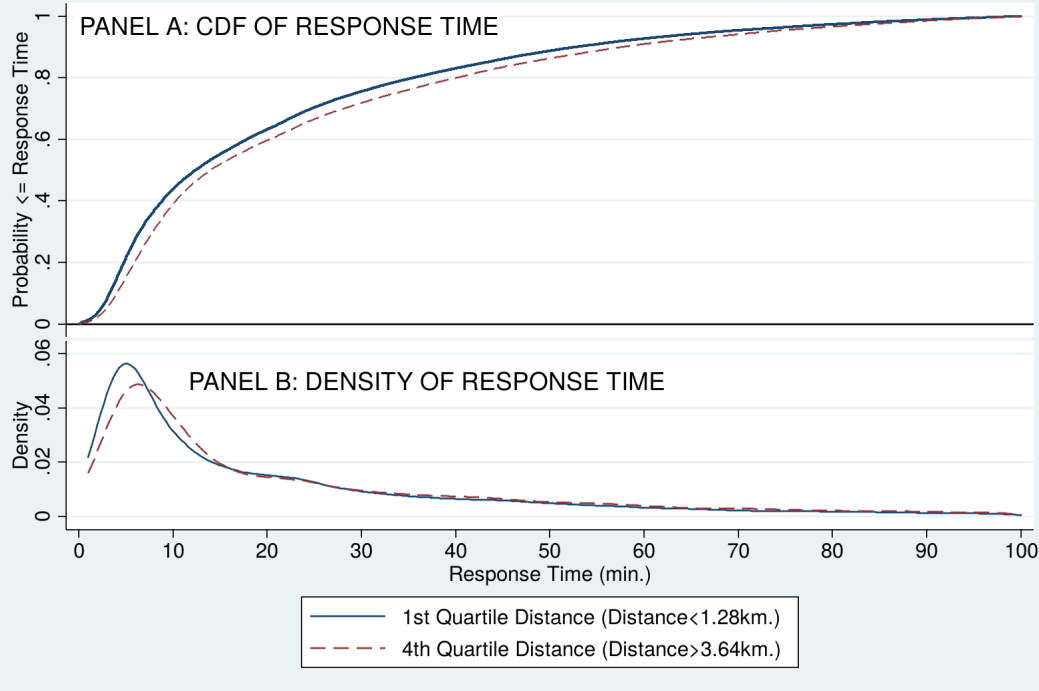
		Effect on Harm	
		High	Low
Effect on Clearance	High	Fast	Fast
	Low	Fast	Slow

Panel B: Response when Distance High

		Effect on Harm	
		High	Low
Effect on Clearance	High	Slow	Slow
	Low	Slow	Slow

This figure displays an example of hypothetical response times, by crime type and by distance to the response station. We divide crimes into four types, depending on: (a) whether rapid response has a significant effect on preventing harm to person or property, and (b) whether rapid response has a significant effect on the likelihood of a clearance. In Panel A, we assume that distance is low and therefore that response time is unconstrained. As a result, we hypothesise that response time will be fast unless rapid response has no effect on either potential harm or the likelihood of a clearance. In Panel B, we assume that distance is high, which constrains response time to being slow for all crimes. The three crime types in the left and top of the tables represent, in a LATE framework, the set of compliant crimes. The crime type in the bottom right is the 'never taker' crime.

FIGURE 9: DISTRIBUTIONS OF RESPONSE TIME BY DISTANCE



TABLES

TABLE 1: SUMMARY STATISTICS

Panel A: All Crimes					
	Mean	Median	SD	Min	Max
Cleared	.38	0	.48	0	1
Time to Clearance (days)	34.47	4	113.44	0	2218
Immediate Arrest	.12	0	.32	0	1
Suspect Named	.24	0	.43	0	1
Response Time (min.)	73.3	16.82	315.01	.07	21613.58
Distance to Station (km.)	3.25	2.26	3.68	0	19
Grade 1	.31	0	.46	0	1
Grade 2	.69	1	.46	0	1
Violent Crimes	.24	0	.43	0	1
Theft Crimes	.53	1	.5	0	1
Other Crimes	.23	0	.42	0	1

Panel B: Crimes in Boundary Cells					
	Mean	Median	SD	Min	Max
Cleared	.33	0	.47	0	1
Time to Clearance (days)	45.32	5	143.1	0	1676
Immediate Arrest	.1	0	.3	0	1
Suspect Named	.21	0	.41	0	1
Response Time (min.)	76.9	18.85	334.47	.08	20051
Distance to Station (km.)	7.25	4.27	6.28	.01	18.99
Grade 1	.3	0	.46	0	1
Grade 2	.7	1	.46	0	1
Violent Crimes	.23	0	.42	0	1
Theft Crimes	.57	1	.49	0	1
Other Crimes	.2	0	.4	0	1

Panel A reports summary statistics for all crimes in the baseline sample (N=306606), while Panel B is based on the subsample of crimes occurring within cells encompassing more than one division, i.e. 'Boundary Cells' (N=22196). 'Cleared'=1 if the crime was cleared. 'Time to Clearance' is the difference between the clearance date and the crime date (it is computed only for cleared crimes). 'Immediate Arrest'=1 if the police made an arrest within 15 minutes of reaching the crime scene. 'Suspect Named'=1 if a suspect was reported to the police by a victim or witness to the crime. 'Response Time' is the number of minutes between the creation of the incident by the handler taking the call and the arrival of the response officer to the scene of the crime. 'Distance to the Station' is the geodesic number of kilometres between the scene of the crime and the closest response station. 'Grade 1'=1 if the incident was allocated a target response time of less than 15 minutes. 'Grade 2' is defined respectively for 60 minutes. 'Violent Crimes'=1 if the Home Office-classified crime type is either Violent Offenses, Sexual Offenses or Robbery. 'Theft Crimes'=1 if the crime type is Theft. 'Other Crimes'=1 if the crime type is Criminal Damage/Arson, Public Order Offenses, Possession of Weapon or Miscellaneous.

TABLE 2: OLS ESTIMATES

VARIABLES	(1) Cleared	(2) Cleared	(3) Cleared	(4) Cleared	(5) Cleared
Log Response	-.053*** (.001)	-.057*** (.001)	-.05*** (.001)	-.048*** (.001)	-.049*** (.001)
Hour/Day/Month/Year	No	Yes	Yes	Yes	Yes
Grade	No	No	Yes	Yes	Yes
Home Office Code	No	No	No	Yes	Yes
Division	No	No	No	No	Yes
R2	.02	.07	.07	.11	.11

This Table displays linear probability models of the clearance rate on response time. The number of observations is 306606. Columns (2)-(5) control for Hour of Day fixed effects, Day of Week fixed effects, Month fixed effects and Year fixed effects. Columns (3)-(5) control for whether the call was regarded as a Priority Response (Grade 2; target response < 60 min.) or as an Emergency Response (Grade 1; target response < 15 min.). Columns (4)-(5) include fixed effects for the type of crime, following the UK Home Office classification code. Crime types include Violent Offenses, Sexual Offenses, Robbery, Theft Offenses, Criminal Damage/Arson, Public Order Offenses, Possession of Weapon and Miscellaneous. Column (5) controls for the 11 territorial divisions (North, South, Salford, Tameside, Stockport, Bolton, Wigan, Trafford, Bury, Rochdale, Oldham). Robust standard errors in parentheses.

TABLE 3: BALANCING TEST 2
Log Number of Crimes on Log Distance

VARIABLES	(1) LogCrimes	(2) LogCrimes
Log Distance	-0.075** (0.032)	-0.010 (0.009)
R-squared	0.004	0.609
Cell X Year F.E.	No	Yes
Division F.E.	No	Yes
N	57731	57731

An observation is a UK census output area and year combination.

Standard Errors in Parentheses Clustered by Division X Year.

TABLE 4: 2SLS ESTIMATES

MODEL DEP. VARIABLE	(1) Reduced Form Cleared	(2) First Stage Log Response	(3) Second Stage Cleared
Panel A: Naive			
Log Distance	-.048*** (.006)	.174*** (.011)	
Log Response Time			-.274*** (.034)
Cell X Year F.E.	No	No	No
Kleibergen-Papp F			228.63
Panel B: Baseline			
Log Distance	-.065*** (.01)	.139*** (.02)	
Log Response Time			-.469*** (.072)
Cell X Year F.E.	Yes	Yes	Yes
Kleibergen-Papp F			53.13

This table displays 2SLS regressions of the clearance rate on response time, using distance to the response station as an instrument for response time. Columns (1), (2) and (3) display the reduced form, first stage and second stage estimates, respectively. All regressions include Hour of Day, Day of Week, Month, Grade, Home Office code and Division fixed effects. Panel A also includes Year fixed effects. Panel B includes Cell X Year fixed effects. Heteroskedasticity and autocorrelation consistent spatial standard errors in parentheses (Conley, 1999). The cross-sectional units are the cells (cutoff = 10km.) and the time units are the years (two lags).

TABLE 5: ROBUSTNESS

MODEL DEP. VARIABLE	(1) Reduced Form Cleared	(2) First Stage (Log) Response	(3) Second Stage Cleared
Panel A: Variables in Levels			
Distance (km.)	-.018*** (.006)	1.711*** (.519)	
Response (min.)			-.011*** (.003)
Observations	298208	298208	298208
Panel B: Wild Bootstrapped Division-Clustered S.E.			
Log Distance	-.065*** [.00]	.139*** [.00]	
Log Response			-.469*** [.04]
Observations	306606	306606	306606
Panel C: Dropping 10% Outliers			
Log Distance	-.065*** (.01)	.11*** (.015)	
Log Response			-.592*** (.094)
Observations	273659	273659	273659
Panel D: Boundary Cells Sub-Sample			
Log Distance	-.077*** (.017)	.176*** (.039)	
Log Response			-.44*** (.098)
Observations	22196	22196	22196
Panel E: Weighting by Distance to the Border			
Log Distance	-.069*** (.009)	.138*** (.018)	
Log Response			-.499*** (.09)
Observations	306606	306606	306606

This table displays robustness tests to the baseline findings in Table 4 (Panel B). Columns (1), (2) and (3) display the reduced form, first stage and second stage estimates, respectively. The dependent variable in Column (2) is the log of response time, unless otherwise noted. All regressions include the baseline set of Hour of Day, Day of Week, Month, Cell X Year, Grade, Home Office code and Division fixed effects. Standard errors are HAC spatial (Conley, 1999) unless otherwise noted. The regressions in each panel deviate from the baseline regressions in the following way. In Panel A, Distance and Response Time are in levels, instead of logs (the dependent variable in Column (2) is also in levels). In Panel A we reduce the impact of outliers by dropping observations with a response time above 500 minutes. In Panel B, the standard errors are clustered at the Division level (number of clusters = 11). Estimated p-values based on the wild bootstrap of Cameron, Gelbach, and Miller (2008) are provided in square brackets, instead of standard errors. In Panel C, 5% of observations have been dropped at each tail of the response time distribution. In Panel D, the analysis is restricted to the sub-sample of crimes occurring in boundary cells (i.e. cells encompassing more than one division). In Panel E, we weight every observation by (the log of) the inverse of the distance to a division border.

**TABLE 6: EVIDENCE ON
NON-RESPONSE POLICE STATIONS**

VARIABLES	(1) Cleared	(2) Log Response
Log Distance (Non-Response)	.002 (.007)	.012 (.027)

This table displays OLS regressions of Cleared and Log Response Time on distance to police stations that are the base of a neighbourhood team but not of a response team. The regressions are identical to those of Columns (1) and (2) in Table 4 Panel B, except for the independent variable of interest. All regressions include Hour of Day, Day of Week, Month, Cell X Year, Grade, Home Office Code and Division fixed effects. Heteroskedasticity and autocorrelation consistent spatial standard errors in parentheses (Conley, 1999). The cross-sectional units are the cells (cutoff = 10km.) and the time units are the years (two lags).

TABLE 7: OTHER LEFT HAND SIDE VARIABLES

Panel A	(1)	(2)	(3)
MODEL	Reduced Form	First Stage	Second Stage
DEP. VARIABLE	Log Time	Log Response	Log Time
Log Distance	.113*** (.047)	.12*** (.029)	
Log Response			.944*** (.393)
Mean Time to Clearance			34.47
Kleibergen-Papp F			10.54

Panel B	(1)	(2)	(3)
MODEL	Reduced Form	First Stage	Second Stage
DEP. VARIABLE	Suspect Named	Log Response	Suspect Named
Log Distance	-.02** (.009)	.139*** (.02)	
Log Response			-.141** (.066)
Mean Suspect Named			.24
Kleibergen-Papp F			53.13

Panel A	(1)	(2)	(3)
MODEL	Reduced Form	First Stage	Second Stage
DEP. VARIABLE	Immediate	Log Response	Immediate
	Arrest		Arrest
Log Distance	-.029*** (.006)	.139*** (.02)	
Log Response			-.208*** (.04)
Mean Immediate Arrest			.12
Kleibergen-Papp F			53.13

This table displays 2SLS regressions equivalent to the ones in Table 4 (Panel B) but with different dependent variables. Columns (1), (2) and (3) display the reduced form, first stage and second stage estimates, respectively. All regressions include the baseline set of Hour of Day, Day of Week, Month, Cell X Year, Grade, Home Office code and Division fixed effects. In Panel A, the dependent variable is (log of) the number of days that it took the police to clear the crime, conditional on eventual clearance. In Panel B, the dependent variable is a dummy taking value 1 if a suspect was named to the police by a victim or witness to the crime. In Panel C, the dependent variable is a dummy taking value 1 if the police made an arrest within 15 minutes of reaching the crime scene. Heteroskedasticity and autocorrelation consistent spatial standard errors in parentheses (Conley, 1999). The cross-sectional units are the cells (cutoff = 10km.) and the time units are the years (two lags).

TABLE 8: HETEROGENEITY OF IV ESTIMATES

Panel A: Cleared	(1) Violent	(2) Theft	(3) Other
	-.24***	-.681***	-.35***
	(.078)	(.085)	(.061)
P-value \neq (1)		0	.028
P-value \neq (2)			0
Mean Cleared	.47	.3	.44

Panel B: Suspect Named	(1) Violent	(2) Theft	(3) Other
	.035	-.322***	-.011
	(.078)	(.068)	(.055)
P-value \neq (1)		0	.256
P-value \neq (2)			0
Mean Suspect Named	.46	.13	.26

Panel C: Imm. Arrest	(1) Violent	(2) Theft	(3) Other
	-.13***	-.261***	-.202***
	(.052)	(.041)	(.04)
P-value \neq (1)		.001	.036
P-value \neq (2)			.034
Mean Immediate Arrest	.16	.08	.16

Every Panel displays the estimated coefficients from a single regression. In every regression the population of crimes has been divided into three crime types. The displayed coefficients are for the effect of response time on the Panel dependent variable for the type described in the column. In every regression the instruments are the interaction of distance with the crime type dummies. In Panel A, the dependent variable is Cleared. In Panel B, the dependent variable is a dummy taking value 1 if a suspect was named to the police by a victim or witness to the crime. In Panel C, the dependent variable is a dummy taking value 1 if the police made an arrest within 15 minutes of reaching the crime scene. All regressions control for Cells X Year, Hour of Day, Day of Week, Month, Division, Grade and Home Office Code fixed effects. None of the control variables are interacted with the group dummies. Heteroskedasticity and autocorrelation consistent spatial standard errors in parentheses (Conley, 1999). The cross-sectional units are the cells (cutoff = 10km.) and the time units are the years (two lags). The means for the response time variable for Violent Crimes, Thefts and Other Crimes are 69.94, 75.63 and 71.46, respectively. The Kleibergen-Papp F-statistic is 18.29.

TABLE 9: COST BENEFIT ANALYSIS

Panel A: Hiring one additional police officer		
	Incarceration Cost	-£62,840
	Criminal Justice System Costs	-£14,391
	Benefits through Crimes Prevented (Incapacitation)	£140,636
	Benefits through Crimes Prevented (Deterrence)	£14,443
	Interim Benefit	£77,851
	Payroll Cost	-£45,745
	Ratio	170%
Panel B: Relocation of all police stations		
	Incarceration Cost	-£7,200,072
	Criminal Justice System Costs	-£1,644,355
	Benefits through Crimes Prevented (Incapacitation)	£16,069,256
	Benefits through Crimes Prevented (Deterrence)	£1,650,697
	Break-Even Cost per Station	£369,814

This table displays the costs and benefits of hiring one additional police officer (Panel A) and relocating all the police stations to alternative, optimally chosen, locations (Panel B). Both policies are hypothesised to be implemented in 2014. In both panels we present separately the benefits in terms of the crimes prevented through the incapacitation and deterrence channels. Because incapacitation requires incarceration and criminal justice system costs, these are also presented separately. In Panel A, we calculate the interim benefit (costs and benefits through the incapacitation and deterrence channels) and the ratio between the interim benefit and payroll cost of the additional officer. In Panel B, all costs and benefits are aggregated over ten years under the assumption of no discount rates. In the bottom row, we present the maximum cost per station that would make the policy cost effective. It is calculated as the interim benefit (costs and benefits through the incapacitation and deterrence channels) divided by 24 (the number of response stations in 2014).

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