Crime Reporting: Profiling and Neighbourhood Observation[1][2]

Siddhartha Bandyopadhyay
Department of Economics,
University of Birmingham,
Edgbaston, Birmingham B15 2TT, UK.

Kalyan Chatterjee
Department of Economics,
The Pennsylvania State University,
University Park, Pa. 16802, USA.

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Abstract

We consider the effect of giving incentives to ordinary citizens to report potential criminal activity. Additionally we look at the effect of "profiling" certain groups. In the first model, we focus on two kinds of profiling. If profiling means that police single out the profiled group for more investigation, then crime in the profiled group decreases. If profiling manifests itself through biased reporting by citizens, crime in the profiled group actually increases. In the second model, we consider a neighbourhood structure where individuals get information on possible criminal activity by neighbours on one side and decide whether to report or not based on the signal. When costs of reporting are low relative to the cost of being investigated, costs of investigation are increasing in the number of reports and there is at least one biased individual, we show there is "contagion equilibrium" where everyone reports his or her neighbour.

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1 Introduction

In the last few years, the idea has once again surfaced that private citizens should be encouraged to report on "suspicious" activities in their neighbourhood, presumably because neighbours are in the best position to detect incipient criminal activity and are likely to be most severely affected by such activity. The former US Attorney-General, John Ashcroft, in fact had proposed a formal programme, Operation TIPS (Terrorism Information and Prevention System), to encourage such reporting, though this programme was eventually not approved by Congress. A report in the Washington Post (excerpted in the Manchester Guardian Weekly of Nov. 26-Dec.3, 2004) notes that in Moscow, the city council passed a law to create "public order councils" in neighbourhoods, who would be "keeping an eye on the people next door".

The examples above pertain to spatial neighbourhoods but the issue is more general than this. Potential whistleblowers in corporations are able to observe signals indicating possible crimes among their co-workers. Tax authorities encourage reporting from individuals about potential violators they might suspect.[1]

Another feature of trying to direct resources to detect criminal activity has been to 'profile'certain groups of people for particular attention. As an example it is often believed that blacks are subject to stop and searches more than whites in certain states in the US[2]. Studies in the U.K. and Canada also show prevalence of racial bias in stop and searches[3].

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[1] As an example see http://www.endfraud.co.uk/Tax%20Fraud.html which encourages U.K. residents to report tax fraud.

[2] Whether this represents bias or simply arrest maximising behaviour is of course not entirely clear. Knowles, Persico and Todd (2001) look at motor vehicle searches and find police behaviour 'consistent with the hypothesis of no racial prejudice against African-American motorists'.

Lambert (see http://www.lamberthconsulting.com/about-racial-profiling/research-articles.asp) however contends that there is profiling and one cannot, from the evidence available, support the the theory that stopping more blacks yields higher drug arrests per stop.

[3] See http://www.cbc.ca/news/background/racial_profiling/

for some discussion about prevalence of racial profiling in Canada. See also http://www.irr.org.uk/2004/july/ak000006.html which discusses how racial profiling is considered an effective anti terror tool by many in the UK. It notes that 'From 2001/02 to 2002/03, there was a fourfold increase in the number of Asians stopped and searched

The rationale for providing incentives to individuals to report suspicious activities has to do, presumably, with the free rider problem and with the limited resources available to the police making it impossible for them to discover crime everywhere without help. Thus, the authorities provide various incentives, which lower the cost of reporting for citizens who notice something suspicious. This paper seeks to show that perverse and unintended consequences could follow in equilibrium from such incentives, well-intentioned though they might be. We focus attention on how such consequences can appear.

Proposals to have neighbours informing on each other have naturally raised concerns about civil liberties and the right to privacy. However, our more prosaic concern here is about the effectiveness of such neighbourhood surveillance in the absence of any appropriate standards of what constitutes suspicious behaviour.

The aspect of encouraging people to report we wish especially to consider is that of innocent citizens having to face costly police interrogation if someone reports on them. In the past it has been noted that in the presence of the possibility of such interrogation, people often tried to divert attention from themselves by reporting other people. The following incident from the infamous McCarthy era serves to highlight the chain reaction of inducing people to report. 'Larry Parks agreed to give evidence to the House Un-American Activities Committee (HUAC)...[who] insisted that Parks answered all the questions asked. The HUAC had a private session and two days later it was leaked to the newspapers that Parks had named names. Leo Townsend, Isobel Lennart, Roy Huggins, Richard Collins, Lee J. Cobb, Budd Schulberg and Elia Kazan, afraid they would go to prison, were also willing to name people who had been members of left-wing groups.'[4] While law enforcement chased these people, it is quite plausible that people genuinely pursuing subversive activities were having a field day. Present day efforts to encourage anonymous ordinary citizens to alert the police to undesirable activities may have similar effects.[5]

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under the Terrorism Act 2000.'

[4] See, for example the website below from which the lines are taken http://www.spartacus.schoolnet.co.uk/USAmccarthyism.htm

[5] A recent police investigation at Art Car Museum, an avant-garde gallery in Houston, on the basis of a phone call is just one of the several "red herrings" that law enforcement is chasing in what many have dubbed as the New McCarthyism (see Matthew Rothschild's articles in the Progressive http://www.progressive.org/0901/roth0102.html for several more

Of course, all this does not imply that such neighbourhood reporting does not have its uses. The net effectiveness of encouraging such reporting could be positive or negative and this is still an open question, one on which this paper tries to shed some light.

In the first model in this paper people are grouped (or profiled) in two categories. Police observe reports about the individuals in the two groups and implement an optimal investigation strategy. There is a cost of investigating a site, which we assume differs across the two groups, and a cost of being investigated. If an investigation is made and a crime has indeed been committed, the criminal is apprehended and removed. If the criminal is apprehended, the criminal's neighbour gets positive payoffs in having the criminal removed from the neighbourhood. (Other people might get such benefits as well.)

We consider perfect Bayesian equilibrium crime rates, reporting and investigation strategies in this environment. We examine the effect of profiling on crime rates across profiled and non-profiled groups[6] We model *profiling by observable characteristics* in two different ways. The first approach is to assume that the profiled group is given "priority for investigation" by the police and hence the cost of investigating a report on a member of such a group is lower. This leads to a *higher* probability of crime in the *non-profiled* group. More interestingly, we can also conceive of profiling as a lower ability by the potential reporter to distinguish suspicious from innocent activities by a profiled group member. This leads to more reporting of the profiled group members and also a *higher prior* probability of crime in the profiled group. This is particularly interesting because higher reporting in fact leads to higher crime in the group more reported on. This occurs as a result of police rationally taking into account the bias in reporting when investigating the group who face biased reporting. It turns out that this, in equilibrium, lowers the intensity of investigation that a criminal faces, to make it more profitable for that group to commit crime *even after* it accounts for the fact that it will be reported on more frequently.

Finally, we modify the model making use of an explicit neighbourhood structure, the simple one where a finite number of agents are placed around a

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illustrations).

[6] The *crime rate* is the ex ante probability that an agent will commit a crime. Since all sites are ex ante identical, this probability is the same for all sites in symmetric equilibrium. Of course, if reports are informative, the probability that a crime has actually been committed, given reports, could differ across sites.

circle. An individual can observe the neighbour on his or her right and report on that neighbour, given the signal he or she receives. The police force is divided into precincts and police in each precinct can ask for help from the precinct on their right as well. Costs of investigation are increasing in the number of reports. Costs of reporting are low and there exists one person who will always report her neighbour, if this neighbour is of a different type. This is commonly known, as is the existence of the person in fact being next to someone of a different group. In this environment there is an equilibrium where all N sites get reported on, through a kind of "contagion" effect. In fact, it turms out if costs of reporting are low in comparison to the cost of interrogation, there is no informative equlbrium.

The message we get is that the relation between crime and incentives from crime reporting is fairly complex and incentives for crime reporting may in fact lead to an increase in crime. Hence, the policy of encouraging increased vigilance about neighbours needs re-examination not just from the angle of intruding on the privacy of people but also in terms of its effectiveness in crime prevention.[7]

2 Related literature

There is a large literature on crime starting from the seminal work by Becker (1968) who first analysed crime as an economic decision. Since then there have been several papers extending Becker's work and developing several aspects of crime and crime fighting policies. In particular, there are papers examining the relationship between law enforcement and crime rates. They include papers which have generated multiple equilibria as in Sah (1991) where similar economies could reach different equilibrium crime rates with a fixed level of resources devoted to law enforcement. The variation in these papers often arise from the channel through which multiplicity arises and most of them have a general equilibrium flavour. Examples include Fender

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[7] There are of course associated general equilibrium effects as an increased spending on prevention of potential terrorist activities reduces the resources to spend on other criminal activities thereby encoraging such activities. As noted in a recent article in the New York Times 'the war on terrorism is also depleting law enforcement resources' and several states have seen an increase in crime rates. We wish to concentrate, however, on the more striking issue that having to act on an increased number of potential threats following increased vigilance may not, even after a budget increase, decrease such activities. (The NYT June 7, 2003 'As Budgets Shrink, Cities See an Impact on Criminal Justice' by Fox Butterfield.)

(1998) and Burdett, Lagos and Wright (2003). This has some empirical support as well. In particular, the issue of wide variation in crime rates has been addressed using a neighbourhood structure by Glaeser, Sacerdote and Scheinkman (1996). They work out the effect that neighbours have on behaviour; having criminal neighbours induces people to commit crime. Unlike their work, everyone in our model behaves completely rationally. In terms of the broad debate on public vs. private enforcement of law (see the classification and discussion in Polinsky and Shavell, (2000) and references therein), our model falls somewhere in between. While enforcement is by a public law enforcement authority, the selection of the sites to investigate depends on neighbourhood reports.

There are of course papers which look at the effect of crime reporting (by victims) as in Goldberg and Nold (1980) which does an empirical analysis and Garoupa (2001) who looks at a theoretical model where victims decide whether or not to report crime. Unlike in our model, encouraging reporting always reduces crime rates. Our paper is also related to the debate on statistical profiling (see for example Eeckhout, Persico and Todd, 2001). On a related issue, Eeckhout, Persico and Todd (2005) study optimal policing with commitment and show that announcing random 'crackdowns' can be optimal. Even though the paper does not look at crime reporting, allowing the police to credibly announce that not all reports may be investigated with equal intensity (as they do) may lead to potentially interesting results in our framework. We discuss this further in the section on profiling and in the conclusion. In terms of modelling, mention may be made of some similarity that this paper has with auditing models (see for example Reinganum and Wilde (1986)). There are, of course, many papers using a local observation approach in other fields (e.g. Ellison,1993, Eshel, Samuelson and Shaked, 1998, Chatterjee and Xu, 2004), though the agents are not fully rational in most of these papers (an exception is Xue, 2003). Methodologically, the approach adopted in this paper is similar to that in the papers inspired by global games, see for example, Morris (2000).

In summary, we study the effects of crime reporting on crime, looking at how this (act of reporting) interacts with the decision to commit crime and can perversely affect crime.

3 The model and notation

3.1 Agents and sites

There are a finite number $N \geq 3$ of people[8], each located at a single site on a circle. Agent $i \in N$ learns the value $x_i \epsilon \{0, 1\}$ [9], where x_i denotes person i's private benefit from crime. The probability that $x_i = 1$ is given by a. As mentioned, to abstract from the free rider problem, we assume that each person has only one observant (or nosy) neighbour. Agent i after learning her value of x_i decides whether to commit a crime or not which we denote by $d_i = 1$ (commit a crime) or 0 (not commit a crime). The decision leads to an observable signal, s_i for site i, which also takes values of 0 or 1.We assume the following signal structure; if $d_i = 1$, $s_i = 1$ and if $d_i = 0$, s_i can be 1 with probability $1 - \xi$ and 0 with probability ξ. The quantity ξ represents the correct identification of non-suspicious behaviour and is therefore affected by possible errors or biases. After observing signals emitted by her neighbour, an agent has to decide whether to report a site or not. To make things stark we have assumed that crime always generates a signal. What we need is simply the probability of crime, given the signal, to be higher than the probability given no signal. The agent incurs a cost of reporting η per report[10] and also, if she has been reported herself and is investigated, a cost of being investigated of γ. This cost of interrogation γ is independent of whether the person is a criminal or not. The reporting decision is denoted $\rho_i \in [0, 1]$ where $\rho_i = (\rho_{i,i+1})$ denotes the reporting probabilities of i on $i + 1$. These will depend on whether $d_i = 1$ or 0 [11]and on the value of the signal s_{i+1}. We assume that Player i does not observe her own signal s_i.

There is a social benefit of apprehending a crime at site i which we denote

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[8] Typically, we think of N as large, though this is not used in any proofs.

[9] The lower bound of the support might be negative rather than 0, in which case there will be some expected proportion of the population who would never commit a crime. While it is possible to incorporate such an assumption into the model, it would necessitate considering some special cases that we are able to ignore here which would detract from the main focus of our analysis.

[10] As we are looking at the effects of reducing the cost of reporting, we think of η as typically "small", perhaps even close to 0. (The penalty for false or misleading reports, which could increase η, is not practicable here because the signal s is noisy. Moreover, it would increase the cost of reporting in expected terms).

[11] The reporting decision is made after the actual decision to commit crime or not, so even though d_i denotes the probability of crime, it takes on values 0 or 1 in any actual realisation of play.

by K. The benefit to the neighbour on the left is assumed to be 1, where $K \geq 1$. [12] The apprehended criminal incurs a penalty $\theta > 1$. The way we interpret this is as follows. Removing a criminal prevents future crime and hence benefits the neighbour and possibly others as well. Thus, there is a direct benefit of reporting. In considering whether to investigate a site the police do not consider the criminal's disutility from apprehension. While this is unlike what is assumed in some of the economic literature on crime (see Kaplow and Shavell, 2002 for discussion on this issue), as long as the criminal's benefit from crime is lower than the cost of crime all our results go through.[13]

3.2 The police

The police are modelled here as separate from the agents. This means that we rule out any nexus between the police and the community as well as any benefits that may accrue to the police from having crime reduced if the police also lived in the neighbourhood. This makes the model tractable and serves as a good approximation for communities where such interaction is minimal. An investigation strategy maps from the reports made about each site into an investigation probability of that site and is denoted by $\omega : [\{0,1\}^N \rightarrow [0,1]^N$. Let $C(r)$ be the cost of investigating a site if reports have been received about r sites. We assume that $C(r)$ is either flat or (weakly) increasing in r . This assumption is examined in Section 5, where $C(.)$ is increasing in r.

We now derive the optimal behaviour for the police. This can be summarised by the follwoing lemma.

Lemma 1 *The police investigation policy is as follows: For* $\rho > 0$, *if* $Ku_i > C(r)$, *set* $\omega = 1$. *If* $Ku_i < C(r)$, *set* $\omega = 0$. *If* $Ku_i = C(r)$, *set* $\omega \epsilon [0,1]$ *where* u_i *is the conditional (given the reports) probability of crime in site* i. *If* $\rho = 0$, *set* $\omega = 1$,*if* $Ku^i < C(r)$. *If* $Ku^i < C(r)$, *set* $\omega = 0$. *If* $Ku^i = C(r)$, *set* $\omega \epsilon [0,1]$ *where* u^i *is the unconditional probability of crime in site* i.

Proof. This is clearly true, given the costs and benefits of investigation of a site, with K being the total benefit from apprehending and removing a criminal. ■

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[12] Another way of writing this is that the benefit of removing the criminal is K from the point of view of the police and 1 from the point of view of the individual.

[13] As pointed out in Winter (2008), both are valid social objectives though they lead to different expenditures on crime.

In the next section we analyse the issue of profiling and spell out the additional assumptions we make.

4 Profiling

One of the more visible features of the policy of encouraging untrained individuals to report suspicious activities has been the importance these individuals give to observable characteristics, such as race, age or gender. In similar vein, police often pay more attention to this observable characteristic in deciding whether to chase up reports or not.[14] We consider these two types of bias separately. Initially, we suppose that the public is unbiased but the police preferentially investigates those with some particular observable characteristic. We then assume the police is unbiased, but the public engages in profiling.

Recall that we assume that $x_i, s_i \epsilon \{0, 1\}$ for all sites i. In this section, the neighbourhood structure plays no role. However, we suppose there is an observable characteristic A which can take on values A_0 and A_1. What this means is that agents could face different probabilities of the random variable x based on whether A is A_0 or A_1, though we shall assume away this possibility to present the results in as simple a way as possible. Denote $P(x = 1 \mid A_j) = a_j$, $j \in \{0, 1\}$. We assume $a_0 = a_1 = a$, (i.e. the characteristic j is a priori uninformative).

Given the value of x_i, agent i chooses $d_i \, \epsilon \, [0, 1]$. A signal s_i is generated. To recall, if $d_i = 1$, $s_i = 1$. If $d_i = 0$, $s_i = 0$ with probability ξ and $s_i = 1$ with a probability $1 - \xi$. As mentioned, we assume that the signal generated by i is seen only by $i - 1$, so that we can ignore the free rider problem. The benefit to having a criminal removed is 1 for the criminal's neighbour.

In order to model police profiling, we suppose the cost c_0 incurred in investigating any report about group A_0 is lower than the cost c_1 incurred in investigating a report about group A_1.[15] The way we rationalise this assump-

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[14] We have had the well-known instance in the UK of a Brazilian being described as "Asian-looking" by an eyewitness, who then discovered other suspicious features about him, such as the fact he was wearing a coat because he felt cold. See http://news.bbc.co.uk/1/hi/uk/4706787.stm for an acount of this incident.

[15] We could have adopted stronger behavioural assumptions, for example that a signal of 1 from a member of group A_0 is reported and investigated with probability 1 but the consequences of this are relatively easy to see and they are incompatible with any kind of equilibrium behaviour.

tion is to think of the police having incurred a fixed cost of investigating the profiled group (perhaps because that group has been more crime prone in the past and so the police have already gathered some preliminary information on that group when making this fixed investment) so that the variable cost of investigating is lower.

We can calculate the posterior probabilities of crime, u_j, given the priors and the value of the signal. Denote by α_j the probability with which an agent of group j will commit crime conditional on getting a benefit of 1. Note that if $s_i = 0$, $u_j = 0$, regardless of i or j. Denote by $d_{ij}(1)$ the decision to commit crime if $x_i = 1$ and by $d_{ij}(0)$ the corresponding decision if $x_i = 0$, by individual i in group j. Similarly $\rho_j(1)$ denotes the reporting decision conditional on a signal of 1 and $\rho_j(0)$ reporting conditional on s_i =0. The following calculation follows from Bayes' rule.

Lemma 2 *$P\ (d_{ij} = 1 \mid s_i = 1)$ is given by*

$$u_j = \frac{a_j \alpha_j}{a_j \alpha_j + (1 - a_j \alpha_j)(1 - \xi_j)} \tag{1}$$

Proof. Follows from Bayes rule. ■

We now characterise the unique equilibrium in this set up.

Proposition 1 *If $Ka_j > \frac{c_j}{K} > \eta$, the behavioural strategy profile $(d_{ij}(1), d_{ij}(0), \rho_j(1), \rho_j(0), \omega_j)$ constitutes a Perfect Bayesian equilibrium of the profiling game. The only non-uniqueness arises if there is a (unique) value of $\rho_j \in (0,1)$ as well as $\rho_j = 1$ as another solution.*

(i) $d_{ij}(1)$ is chosen so as to make $u_j = \frac{c_j}{K}$,using the Bayes' Theorem calculations above.

(ii) $\frac{1}{\gamma\xi+\theta} = \rho_j(1)\omega_j$, if both ρ_j and ω_j are positive and $-\eta + \omega_j u_j \geq 0$. If no report is observed, the equilibrium inference is $\Pr(d_i(1) = 1) = u_j(0) < \frac{c_j}{K}$ and $\omega_j = 0$.

(iii) If $-\eta + \omega_j u_j < 0$, $\rho_j(1) = 0$ and $\omega_j = \frac{1}{\theta}$.In this case, because there is no report, $u_j^i = a_j \alpha_j = \frac{c_j}{K}$. If a report is made (out of equilibrium), u_j is believed to be strictly greater than $\frac{c_j}{K}$ and $\omega_j = 1$.

(iv)If $d_{ij}(0) = 0, \rho_j(0) = 0$.

Proof. We break up the proof into a series of steps for convenience.

1. Consider $s_i = 0$ for some i of observable characteristic j.Then whoever observes this signal should have $\rho_j = 0$, because $u_j = 0$ and $\eta > 0$.

2. If $s_i = 1$, $\rho_j = 0$ if $\eta > u_j\omega_j$. In such a case, $\omega_j = 0$ if $Ka_j < c_j$. If this is the case, $d_{ij}(1) = 1$. We do not consider this trivial case further, assuming $Ka_j \geq c_j$.

3. Suppose $\eta > u_j\omega_j$, so no reporting takes place i.e. $\rho_j(1) = 0$. If $Ku_j > c_j$, $\omega_j = 1$, but then $d_{ij}(1) = 0$, since a criminal will be discovered and will get a negative payoff. But then the prior probability of crime $u^i_j = 0$, a contradiction. Therefore if there is no reporting in equilibrium, there can only be a non-degenerate mixed strategy equilibrium, with α_j chosen so as to make $u^i_j = \frac{c_j}{K}$. Note that if c_j is higher, so is u^i_j, even if a_j does not depend on j. The value of ω_j is chosen to make i indifferent between crime and no crime, if $x_i = 1, i.e.\ 1 - (\gamma + \theta)\omega_j = -\gamma\omega_j$, since investigation will take place irrespective of the signal s_i so that $\omega_j = 1/\theta$. Note the police does not observe the signal directly.

4. If η is small enough, $\rho_j(1) > 0$. So now reporting takes place and the investigation depends on the posterior probability of crime u_j. There are two possibilities. (i) If $-\eta + \omega_j u_j > 0$, $\rho_j(1) = 1$. In this case, for $d_{ij}(1) \in (0, 1)$, it must be the case that $1-(\gamma+\theta)\omega_j = -\gamma\omega_j(1-\xi)$, or $\omega_j = \frac{1}{\theta+\gamma\xi}$.(ii) It can also be the case that $-\eta + \omega_j u_j = -\eta + \omega_j \frac{c_j}{K} = 0$. In this case, (substituting $1-(\gamma+\theta)\omega_j\rho_j(1) = -\gamma\omega_j\rho_j(1)(1-\xi)$) $\rho_j(1)$ must satisfy

   $$\rho_j(1) = \min\left\{\frac{c_j}{(K\eta)}\frac{1}{(\theta+\gamma\xi)}, 1\right\} \tag{2}$$

   If η is small enough, (2) will give a value of $\rho_j(1) = 1$. Therefore, for small enough values of reporting cost, reporting takes place with probability 1 in equilibrium and the non-degenerate randomised reporting equilibrium does not exist. Otherwise, we get both possible reporting equilibria.

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The key aspect of this is that A_0 is “profiled" as high priority for investigation and this makes $c_1 > c_0$. Therefore u_1, the posterior probability of crime, is higher for the non-priority group A_1, from (i) in the proposition above. In the equilibrium in which $\rho_j \in (0, 1)$, the probability of investigation is lower and the reporting probability is higher. Note that in this section, we assume a constant unit cost of investigation i.e. we do not investigate dependence of c_1 on the number of individuals of type A_0 reported. As mentioned earlier,the absence of this assumption gives an additional incentive for type A_1 to report on type A_0 neighbours.

The effect on welfare of removing the cost difference between investigating different groups is indeterminate and depends on the proportion of each type and what each type does in equilibrium This is consistent with what Eeckhout, Persico and Todd (2005) find in their model of an optimal crackdown.

A second way to think of profiling is to allow for more reports to occur about the profiled group. This could happen as a result of receiving 'incorrect' signals about the profiled group more frequently. The parameter in the model of this section that corresponds best with the informal stories of individuals of a particular type being treated with suspicion is ξ. A lower ξ means that even when someone in the group (say group 0) has not committed a crime 'false signals' are emitted possibly due to bias of the observer. Consequently, we get the following result using the analysis in the proposition above but making $c_j = c$ and admitting different values of ξ_j for the two groups.

Proposition 2 *If the 'false signal' generated by group* 0 *is greater than that for group 1, i.e.* 1-ξ_0>1-ξ_1, $c_j = c$ *and the other assumptions about the values of* η, γ, θ,K,a *all continue to hold, (i)* $\rho_0\omega_0 > \rho_1\omega_1$, *unless* $\rho_j = 0$ *for both* j, *(ii)* $u_0 = u_1$ *and (iii)* $\alpha_0 > \alpha_1$.

Proof. Parts (i) and (ii) follow from the proof of the previous proposition. Recall that $1 - \xi$ is the probability that a signal of 1 is generated even though $d_{ij} = 0$. That gives us (supressing the sunscripts and for a positiveρ) $\rho\omega = \frac{1}{\theta+\gamma\xi}$ which is decreasing in ξ (and hence increasing in 1-ξ. The posterior probability of crime is given by $\frac{c}{k}$ so is independent of ξ. Part (iii) follows from the fact that the posterior probability of a crime given a report will remain at $\frac{c}{K}$ in equilibrium. In expression (1), the left-hand side is independent of j, by (ii). The denominator on the RHS is higher for $j = 0$. Therefore, the numerator must also be higher to maintain $u_0 = u_1$ and since $a_j = a$, the quantity α_0 must be greater than α_1, ■

Remark 1 *Note that in this case, the posterior probability of crime is the same for both groups. However, the probability that a crime is committed* *is higher for the profiled group. The intuition behind this result is not just that more errors in reporting cause more crime because fear of discovery is lower. Here the error actually causes more reporting and investigation in equilibrium, not less. Reporting and investigation would find less crime on average because of the error (unless α_0 were greater than α_1) and this would lead to the benefit of investigation to be less than the cost and hence not optimal to perform unless 'compensated' by a higher prior probability of crime.*

5 The model with a neighbourhood structure and low reporting costs

The previous section has focused on the effect of profiling of two kinds on the incidence of crime in the group being profiled or not profiled. We now combine the models with biased reporting with a neighbourhood structure and assume that the cost of reporting is 'small' (in a sense to be made more precise in the results). We also introduce a cost of investigation that depends on the number of reports that the police face. We now consider each of these in turn.

(i) *Biased reporting.* Suppose that there exists one person of type A_1 next to a type A_0 right neighbour for whom reporting a neighbour of type A_0 is optimal for both $s_i = 0$ and for $s_i = 1$. Call this a type A individual. All other combinations take optimal decisions given the inference structure with Prob $(s_i = 0 \mid d_i = 0) = \xi$ as before.

(ii) *The neighbourhood structure.* To recall from the model section, players $i, i = 1, 2..N$ are arranged in a circle and numbered clockwise; the signal generated by i is observed by $i-1$ but not by $i+1$. Player i gets a benefit of 1 if the player $i+1$ is removed, if $d_{i+1} = 1$. Each player observes the neighbour's type when the neighbour generates a signal, not at the time of taking the decision on crime.

(iii) *The police investigation decision* takes place in two stages. First, the reports are analysed incurring a fixed cost per report. Then the decision is taken whether to investigate a particular site or not. The sites on the circle are divided into "precincts". A precinct comprises of two sites with one assigned police officer in each precinct. A precinct consisting of sites

$\{i, i+1\}$ can co-operate with a precinct $\{i+2, i+3\}$.[16] There are two possible values of the costs of investigation, c_1 and c_2, the first if a precinct is not at capacity and the second if it is. This captures the fact that costs of investigation are increasing in the number of reports. After all the reports are in, neighbouring precincts with spare capacity "raise their hands". If help is sought and there exists a neighbouring precinct with spare capacity, then the cost is c_1 again and c_2 if there is no spare capacity. Note, we could have assumed that if a precinct operating below capacity offers help then the combined cost of investigation is c_3 with $c_1 < c_3 < c_2$. This simply complicates things without adding anything to the analysis so we work with only two costs.

We recall that the benefit from investigating a site is $u_i K$, where u_i is the posterior probability of a crime having been committed given a report, K is the benefit to society of having a criminal discovered. If an investigation is performed and a crime has been committed, we assume it will be discovered. As before, the cost of being investigated is γ and if an individual has committed a crime, the penalty is θ if the crime is discovered.

5.1 Equilibrium

We investigate perfect Bayes equilibria in pure reporting strategies.

Proposition 3 *There exists an equilibrium, for* $\eta \leq \gamma\frac{\theta-1}{\theta}$ *and* $Ka > c_2$*, in pure reporting strategies, in which* $\rho_{i,i+1}$ *:=the probability of* i *reporting* $i+1$*, is 1, independent of the signal. If a player does not report (off the equilibrium path), beliefs are assumed not to change.*

Proof. The condition on the prior probability a is similar to the one in the previous propositions to rule out trivial pure strategy equilibria. Since in the candidate equilibrium, everyone reports both types of signal, there is no information conveyed by the report and the posterior probability u_i that $d_{ij} = 1$ is simply $a\alpha_j (= u_j^i)$. But $u_i = \frac{c_2}{K}$ in the equilibrium, since c_2 is the cost of investigating, when the precinct is at capacity. Since $s_i = 0$ and

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[16] A general formulation with n persons per precinct and coperation with both left and right precincts would make the analysis more complete, especially in avoiding the asymmetric nature of co-operation among precincts in this model (help is available only with the neighbouring precinct on the right). However, such an analysis, though possible, would not add any more essential qualitative insights.

$s_i = 1$ both get reported with probability 1, a site i is indifferent between crime and no crime if $\omega = \frac{1}{\theta}$ (to ensure that $\alpha \in (0,1)$) as in the preceding propositions. Consider a deviation by a player i, who observes $s_{i+1} = 0$. If she sets $\rho_{i,i+1} = 0$, there is no change in beliefs (by assumption) and the cost of investigating i drops to c_1. But $u_i = \frac{c_2}{K} > \frac{c_1}{K}$, therefore $\omega_i = 1$. Assume $d_i = 0$. Then the deviation is not profitable if the disutility from the increase in probability of investigation (i.e. 1) from $\frac{1}{\theta}$ is greater than the cost of reporting η i.e

$$-\gamma\frac{1}{\theta} - \eta \geq -\gamma, \tag{3}$$

or

$$\gamma\frac{\theta - 1}{\theta} \geq \eta.$$

Note that the larger the penalty θ is, the larger the upper bound on the reporting cost can be for this equilibrium to exist. (The limiting bound is $\eta \leq \gamma$.

To check that it is optimal to report $s_i = 1$, we consider $i - 1's$ reporting problem. Reporting is at least as good as not reporting for the non-criminal if

$$u_i\frac{1}{\theta} - \eta - \gamma\frac{1}{\theta} \geq -\gamma$$

which holds if the preceding inequality holds. Also if $i - 1$ has himself committed the crime, γ is replaced everywhere by $(\gamma + \theta)$, for which the condition holds automatically if it holds for γ. ■

The next question we ask is *whether there is an informative equilibrium,* one in which $s_i = 1$ gets reported and $s_i = 0$ does not.[17]

Proposition 4 *There cannot exist an informative equilibrium if the reporting cost η is sufficiently low in the sense detailed in the proof below and the location of the special "always report" person is (as assumed before) known to his neighbours after the signals and before reporting.*

Proof. Suppose to the contrary there is an informative equilibrium, so that a signal $s_i = 1$ gets reported and a signal $s_i = 0$ does not. We again break up the proof into several steps.

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[17] It is easy to see there is an uniformative equilibrium where no one reports. This is sustained by the rather unpalatable off the path equilibrium belief that the police investigates the person who has reported with probability 1 (see Bandyopadhyay and Chatterjee, 2005 for a characterisation).

(i) Given the assumption that $Ka > c_2$, it must be the case that, if $x_i = 1$, player i randomises between crime and no crime, so $\alpha_i \in (0,1)$. This is because $\alpha_i = 1$ is not an equilibrium choice, given that it leads to certain investigation and $\alpha_i = 0$ is not one because it leads to no investigation. Therefore, Player i must be indifferent between $d_i = 1$ and $d_i = 0$, and therefore $\overline{\omega} = \frac{1}{\theta+\gamma\xi}$, where $\overline{\omega}$ is the overall equilibrium probability of investigation.[18]

(ii) Consider the one type A agent for whom reporting a neighbour of type 0 is optimal for $s_i = 1$ or 0, and let this agent be at site $i-1$.Let agent i be of type 0, who observes $s_{i+1} = 0$. Let $q = (a\alpha + (1-a\alpha)(1-\xi))$, the probability that any site other than i generates a signal of 1 and is therefore reported on in this candidate equilibrium. With u being the posterior probability of crime, given a signal, Ku is the benefit from investigating for the police. We need to consider the various cost intervals in which u can fall. Suppose first that $Ku \in (c_1, c_2)$. Then i knows he will be reported on by $i-1$ and investigated with probability 1 if he does not report. If he does report, he will be investigated with probability 1-$q^2_{(1)}$ i.e will be investigated except when two sites other than i generate a signal of 1.Here $q_{(1)}$ refers to the value of q if α is determined by this particular value of u i.e. $Ku \in (c_1, c_2)$. The gain from reporting will then be $(q^2_{(1)})\gamma = \varrho_1$, say. Therefore, if $\eta < \varrho_1$, i will report $i+1$ even if he observes a signal of 0. Here the value of α is determined from the equation that the ex ante probability of being investigated must be $\overline{\omega}$, if this equation has a solution. If it does not, we go to the next case, where a solution will exist.

(iii) Suppose that $Ku = c_j$, where $c_j \in \{c_1, c_2\}$. Then the police is indifferent between investigating and not for some fixed number of reports and investigates with probability ω when that number is realised (to make the total probability $\overline{\omega}$. If $c_j = c_1$, the probability of being investigated drops from $\overline{\omega}$ to 0 with probability $q^2_{(2)}$, so the condition is now $\eta < q^2_{(2)}\overline{\omega}\gamma = \varrho_2$, with q now being determined by the indifference equation $Ku = c_1$.

If $Ku = c_2$, not reporting will mean a probability 1 of being investigated. Reporting will reduce the probability to $\overline{\omega}$ with probability $q^2_{(3)}$. Let $\varrho_3 = q^2_{(3)}$(1-$\overline{\omega}$)γ. Let $\varrho^* =$min $\{\varrho_1, \varrho_2, \varrho_3\}$. Then for $\eta < \varrho^*$, i will report $i+1$.

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[18] As each person faces an independent draw of x, s one needs to compute probabilities across various cost realisations i.e. one needs to compute probabilties of the cost being c_1 or c_2 which would determine probability of investigation.

(iv) By our assumptions, it is common knowledge that there is one type A person who will report a type 0 person and is next to a type 0 person, and this location is revealed to his neighbours after the signals have been generated but before reporting. Therefore i knows he will be reported on by $i-1$, and will therefore (if the condition holds) report $i+1$, and the contagion will spread so that everyone reports irrespective of the signal. ■

Remark 2 *It is worth remarking that the contagion effect is not an artifact of the rational investigation strategy followed by the police. Indeed, we have proved elsewhere (see Bandyopadhyay and Chatterjee, 2006) that even when police choose a fixed investigation strategy, the contagion result holds. The key elements for the result to hold are that reporting costs should be low, cost of interrogation should be high and more reports can decrease intensity of investigation. In the current paper, note we need only one extremely biased person and the opportunity for that person to exhibit his bias, along with low reporting costs, for informative equilibria to disappear.*

6 Conclusion and extensions

We have presented a game theoretic model of crime and crime reporting to examine the possible effects of profiling and lowering the costs of reporting suspicious activities (signals of crime). We find that what is meant by profiling needs to be clarified to understand its effects. If a group is marked by the police so that it is investigated more intensely following reports crime in the group so profiled goes down. However, if citizens harbour a certain bias about a group and therefore report the group more frequently crime in the group being reported on more often actually goes up. It is interesting to note that if the police are also biased this may not hold-thus an increase in distortions may actually lower crime. Further, we show that when reporting costs are low and interrogation costs are high (a not unnatural scenario post 9/11) reports can be completely uninformative in equilibrium. It is also worth remarking that in a model where people can choose neighbourhoods the presence of type A people next to type A_0 may cause neighbours to move away from type A people leading to segregated neighbourhoods. All this suggests that, while there may be some merit in having citizens direct the police about where to look for possible criminal activity, its effects may turn out to the opposite of what was intended. Thus, a more careful evaluation of the pros and cons of citizen reporting needs to be undertaken.

Several extensions arise naturally from this work. An issue we have mentioned in section 2 is to look at optimal ‘crackdown’ a la Eeckhout, Persico and Todd (2005) in our framework to see how well it deters crime (if at all). Another issue we have touched on, but which needs more investigation, is the general equilibrium effect associated with trying to lower crime of any one type leading to increases in other types of crime (the so called ‘displacement effect’). This is implicitly captured in our optimal investigation model in terms of the increased cost of having to chase more reports, which can be interpreted as the opportunity cost of having less to spend on other types of crimes, but a fuller formalisation of this is left for future work. We also do not tackle the related and interesting issue of whether a neighbourhood watch programme can bring down crime by increasing the accuracy of reports. This is of course of particular interest, as a problem with the kind of reporting that is generally encouraged pays no heed to developing a standard of what could constitute a suspicious activity. Presumably in a successful neighbourhood watch programme the police will invest in training citizens in being able to infer what are suspicious activities. This would be formally equivalent to increasing the accuracy of the signal. Hence, it would be interesting to see what kind of equilibria emerge in such an environment. Another interesting question is whether clustering or dispersion of criminals across sites can lead to different crime rates by leading to different actual number of sites reported . Hence, even for an identical distribution of x_i whether the high x_i are in neighbouring sites or far away can matter in the actual number of criminals in any period. A dynamic extension can thus look at the long run path of crime starting from a particular realisation of x_i, which should yield interesting results. These, along with a more thorough investigation of empirical evidence, remain for future research.

References

Bandyopadhyay, Siddhartha and Kalyan Chatterjee, (2006), 'Crime as a local public bad, neighbourhood observation and reporting', Discussion paper, University of Birmingham

Becker, Gary S, (1968), 'Crime and Punishment: An Economic Approach' *The Journal of Political Economy*, Vol. 76, No. 2. pp. 169-217.

Burdett, Kennneth, Ricardo Lagos and Randall Wright, (2003), 'Crime, Inequality and Unemployment' (forthcoming *The American Economic Review*)

Chatterjee, Kalyan and Susan Hong Xu, (2004), 'Technology Diffusion by Learning from Neighbours', *Adv. in Appl. Probab.*, **36** (2004), no. 2, 355–376

Eeckhout, Jan, Nicola Persico and Petra Todd (2005), 'A Rational Theory of Random Crackdowns' working paper

Ellison, Glenn. (1993), 'Learning, Local Interaction, and Coordination' *Econometrica* Vol. 61, No. 5 (Sep., 1993), pp. 1047-1071

Eshel Ilan, Larry Samuelson and Avner Shaked (1998) 'Altruists, Egoists, and Hooligans in a Local Interaction Model' *The American Economic Review*, Vol. 88, No. 1. March, pp. 157-179.

Fender John, (1999) 'A General Equilibrium Model of Crime and Punishment', *Journal of Economic Behavior & Organization*, July 39(4), pp. 437-53.

Fudenberg, Drew and Jean Tirole, (1991), *Game Theory,* MIT Press, Cambridge, Mass.

Garoupa, Nuno (2001) 'Optimal law enforcement when victims are rational players', Economics of Governance, Springer, vol. 2(3), pages 231-242, November.

Glaeser, Edward L, Bruce Sacerdote; and Jose A. Scheinkman (1996) 'Crime and Social Interactions', *The Quarterly Journal of Economics,* Vol. 111, No. 2., pp. 507-548.

Goldberg Itzhak, and Frederick C. Nold (1980) 'Does Reporting Deter Burglars?–An Empirical Analysis of Risk and Return in Crime' *The Review of Economics and Statistics*, Vol. 62, No. 3, pp. 424-431

Kaplow, Louis and Steven Shavell (2002) '*Fairness Versus Welfare*', Harvard University Press

Knowles, John, Nicola Persico and Petra Todd, (2001) 'Racial Bias in Motor-Vehicle Searches: Theory and Evidence' ,*The Journal of Political Economy,* 109(1), pp. 203-29

________________**(2004)** ‘Estimating Deterrence Effects Using Random Crackdowns: Theory and Evidence’, Working paper

Morris, Stephen (2000), ‘Contagion’, *Review of Economic Studies,* 67, 1, 57-78

Polinsky Mitchell A. and **Steven Shavell**, **(2000)** ‘The Economic Theory of Public Enforcement of Law’, *Journal of Economic Literature*, Vol. 38 No.1 pp. 45-76.

Reinganum, Jennifer and Louis Wilde (1986), ‘Equilibrium Verification and Reporting Policies in a Model of Tax Compliance’**,** *International Economic Review,* **27,** 739-760

Sah, Raaj K (1991) ‘Social Osmosis and Patterns of Crime’, *The Journal of Political Economy*, Vol. 99, No. 6., pp. 1272-1295.

Winter, Harold (2008) ‘*The Economics of Crime-An introduction to rational crime analysis’*, Routledge Press

Xue, Jun (2003), ‘Sustaining Cooperation in the Repeated Prisoner’s Dilemma with Local Interaction’ **,** mimeo, Faculty of Economics, University of Cambridge.