Passenger Profiling, Imperfect Screening, and Airport Security

by Nicola Persico and Petra E. Todd*

The need for greater airport security has recently led to major changes in passenger screening procedures. One important change is the development of a Computer Assisted Passenger Pre-Screening System (CAPPS II), a new tool to select passengers for screening. When boarding cards are issued, CAPPS confirms passengers' identities, performs criminal and credit checks, and retrieves additional information, such as residence, home ownership, income, and patterns of travel and purchases, used to construct a predicted threat rating.[1] Passengers with elevated ratings are subject to searches and baggage inspections and may be questioned. Some other passengers are searched at random. These profiling measures have been challenged in lawsuits alleging unlawful discrimination.[2] Some also question the effectiveness of profiling strategies relative to random searches. A second change in airport security has been an effort to select higher ability screeners and to improve their training (see e.g. U.S. General Accounting Office 2004).

We analyze the implications of these changes for search rates and crime rates within an extended version of a model of police and criminal behavior previously introduced in John Knowles et al. (2001) (henceforth KPT). In KPT, police decide which vehicles to search and motorists decide whether to carry contraband. Absent racial bias, officers maximize the number of successful searches, defined as uncovering contraband such as drugs or illegal weapons. Racial bias is modeled as a reduction in the perceived cost of searching vehicles of certain types of drivers. An implication of biased monitoring is that the equilibrium rate at which contraband is seized (the hit rate) is lower for the groups subject to bias.

Several differences between the airport screening process and the motor vehicle search process limit the applicability of the KPT model. First, the model assumes that screeners know the guilty rates of different identifiable groups when allocating their searches. This assumption may be inappropriate when screeners rarely apprehend violators, and so may not learn the groups' guilty rates. CAPPS can be viewed as a way of aggregating information across airports to facilitate learning. A related problem occurs when screeners cannot easily identify groups, perhaps due to a lack of cultural sensitivity. CAPPS reveals information that screeners may otherwise not discern. However, CAPPS does not does not completely obviate the need for screener ability. Nervousness, or hidden contraband, are only detected by a perceptive screener. In fact, there is reportedly a 24% error rate in detecting weapons in baggage screening (see Attkisson 2002). Thus, searches do not always detect violations.

We extend the KPT model to incorporate the screeners' limited ability to discern groups and to detect violations. We show that the "hit rate" test for racial bias developed in KPT extends to this more realistic case. We then analyze two channels through which airport security might be improved. The first is better targeting of searches. The second is an increase in the detection rate conditional on targeting. Additionally, we consider monitoring strategies when passengers can disguise themselves as other types.

I. The Model. Below, we present an extension of the KPT model that incorporates imperfections in monitoring. There are two groups of passengers, groups 1 and 2, with equal mass of 1. There is a measure S of screeners, each of whom only searches one passenger. Screeners can distinguish whether a passenger belongs to group 1 or 2, but cannot distinguish passengers within each group.

A member of group i derives value v from committing a crime (regardless of whether he is found out). The value v is passenger-specific and is the passenger's private information; v is distributed according to a cdf F_i. The cdf has a density f_i that is bounded below on its support.

A passenger who commits a crime and is searched is detected with probability d_i. High values of d_i mean that, in their searches, screeners are good at detecting criminals. This feature extends the KPT model, where it was assumed that $d_i = 1$ for all i.

A criminal is apprehended only when he is searched and is detected, in which case he incurs a loss l_i. The expected benefit from not committing a crime is zero. Passengers suffer a cost k_i from being searched.

Each screener chooses which group to search to maximize his/her expected utility from searching. Screeners receive a utility of $\beta \geq 1$ from apprehending a member of group 1, and of 1 from apprehending a member of group 2. When the parameter β exceeds 1, we say that the screeners are biased against group 1. The assumption of hit rates maximization agrees with the institutional details uncovered in *Anderson v. Cornejo.* Jan Eeckhout et al. (2004) investigate different objective functions.

II. Analysis. A passenger of group i with value v has an expected utility of committing a crime equal to

$$v - s_i \left(d_i l_i + k_i \right),$$

where s_i denotes the mass of searches devoted to group i. The passenger will commit a crime whenever this quantity exceeds the expected utility of not committing a crime, which is $-s_i k_i$. Thus, the fraction of criminals in group i is $1 - F_i \left(s_i d_i l_i \right)$. The hit rate, i.e., the probability that a search of a member of group i is successful, is

$$H_i \left(s_i, d_i \right) = d_i \left[1 - F_i \left(s_i d_i l_i \right) \right].$$

The hit rate in group 1 is a decreasing function of s_1, while the hit rate in group 2 is a decreasing function of $s_2 = S - s_1$. Figure 1 depicts the hit rates as functions of s_1.

INSERT FIGURE HERE

In equilibrium, screeners must receive the same expected utility from searching either group. Otherwise, screener would only search the group in which that probability is highest, which cannot be an equilibrium because then all passengers of the other group would commit a crime. Denoting equilibrium search intensities with a superscript β, if both groups are searched it must be

$$\beta H_1 \left(s_1^\beta, d_1 \right) = H_2 \left(s_2^\beta, d_2 \right) = H_2 \left(\left(S - s_1^\beta \right), d_2 \right). \tag{1}$$

If $\beta = 1$, i.e., there is no bias, the equilibrium is achieved at s_1^*. If $\beta > 1$ the equilibrium is achieved at the point s_1^β further to the right. The disparity between the equilibrium hit rates, depicted by the dashed thick line, reflects the size of the bias. Thus, we have the first proposition.

Proposition 1 *There is bias against group 1 if and only if the hit rate is lower in group 1 than in group 2.*

This proposition demonstrates the applicability of the KPT "hit rates" test to infer bias to an environment with imperfect detectability.[3] Inferring bias is key to establishing racial discrimination in airport screening. This is because, unlike employment cases which usually fall under Title VII of the Civil Rights act, policing situations are typically covered under Title VI or under the Fourteenth Amendment, whereby plaintiffs must show not only disparate impact but also intent to discriminate. Judge Easterbrook follows a "hit rates" analysis in *Anderson* (See David A. Castleman and Persico 2004).

In what follows we will assume, to fix ideas, that $s_1^* > S/2 > s_2^*$, meaning that group 1 is searched disproportionately in equilibrium.

III. Effect of CAPPS. Systems like CAPPS channel background information to the screener than he/she cannot otherwise see. To the extent that the statistical model that underlies CAPSS can predict criminality, the CAPSS system allows the targeting of searches towards groups with higher levels of criminality. The trade-offs entailed by such a program can be seen in Figure 1. Suppose that, absent a system like CAPPS, screeners cannot distinguish between passengers in groups 1 and 2 and so search both groups with the same intensity $S/2$ Then, the aggregate crime rate is $\frac{1}{2}\left[H_1\left(S/2, d_1\right) + H_2\left(S/2, d_2\right)\right]$, a level indicated by the dash in Figure 1. Theoretically, this crime rate may be higher or lower relative to the level that obtains when screeners can distinguish between the two groups. Whether it is higher or lower depends on the shape of the curves H_1 and H_2. If the curve H_1 is very flat, for example, eliminating a CAPPS-like system will not appreciably increase crime in group 1. That is, removing the capability of distinguishing groups can in fact decrease aggregate crime. (See also Persico 2000 and Bernard E. Harcourt 2004).

With regard to airport searches, we conjecture that dispensing with CAPPS would increase the crime rate since, at least in customs searches, random searches appear much less likely than directed searches to uncover contraband (about six times less likely: see Table 7 in U.S. General Accounting Office 2000). It seems improbable, therefore, that the deterrent effect of searching groups that are so much less likely to commit a crime at a higher rate would more than make up for the decreased deterrence in high-crime groups.

IV. Group-Specific Improvements in Detection Ability. Consider a situation in which a search constitutes a cursory pat-down and a few questions. Suppose that in this process, a criminal passenger of group i gives off a signal which the screener is able to detect with probability d_i. If the signal is detected, the screener engages in a more extensive investigation and discovers that the individual is guilty. If the signal is not detected, either because the screener missed it or because the individual is innocent and so did not emit the signal, the individual is waved through.

Within this simple model, d_i captures the screener's ability to pick up subtle clues that are possibly culture-specific. We are interested in the effect of increasing d_1 on the equilibrium search intensity of group 1. The latter decreases if the curve H_1 shifts downward (refer to Figure 1). That curve shifts downwards if

$$\frac{\partial H_1(s_1, d_1)}{\partial d_1} = \beta \cdot [1 - F_1(s_1 d_1 l_1) - s_1 d_1 l_1 f_1(s_1 d_1 l_1)] \tag{2}$$

is negative. The sign of this expression depends on two countervailing effects. On the one hand, searches of passengers of group 1 become more successful and, therefore, the hit rate on group 1 increases. On the other hand, potential criminals learn that screeners are better at detecting them and are therefore deterred. The latter effect reduces the hit rate. The first effect is negligible when $1 - F_1$ is close to zero, that is, when almost everyone is honest. In that case, expression (2) is negative (recall that f_i is bounded below). This proves the following result.

Proposition 2 *Suppose a sufficiently large fraction of the population is honest. Then, regardless of bias, an increase in the screener's ability to detect criminals in group 1 results in fewer searches of that group and increased expected utility for honest members of that group.*

V. Group-Neutral Improvements in Detection Ability. Consider a situation in which a search represents the cursory examination of hand luggage. Let d be the probability that the screener detects any weapons or other contraband. In this setting, it is natural to assume that $d_1 \equiv d_2 \equiv d$, that is, detection ability is independent of cultural sensitivities of the screener. A high d screener is very competent in screening all luggage.

The equilibrium condition is given by equation (1). We are interested in the effect of an increase in d on the proportion of group 1 passengers searched. A marginal increase in d shifts down both curves H_1 and H_2. The proportion of group 1 passengers searched increases if and only if

$$\beta \cdot \frac{\partial H_1 (s_1, d)}{\partial d} > \frac{\partial H_2 ((S - s_1), d)}{\partial d}.$$

The left hand side of this equation is expressed in equation (2); there is an analogous expression for the right hand side. Whether the inequality is satisfied depends on details of the model, such as the functions f_i and the values of l_i, which are unlikely to be observable. In the absence of such information, we cannot tell whether the inequality is satisfied and, therefore, whether an increase in d increases the proportion of members of group 1 who are searched. We conclude that there is no reason to believe that increasing the general competence of screeners in the sense described above would result in less cost for group 1 members.

VI. Extension: Endogenous Characteristics. A group 1 passenger bent on committing a crime may find it expedient to disguise himself as, or delegate the crime to, a member of another group which is apprehended with a lower probability. In this section we show that the results are robust to this modification. To this end, we augment the model by allowing members of group 1 to, at a cost δ, hire an agent in group 2 to whom the crime is delegated. We assume that the agent would not have otherwise committed the crime, and that δ is sufficiently large to induce the agent to commit the crime. A group 2 agent is searched with intensity s_2 and detected with probability d_2. However, if the agent is detected, the principal suffers l_1. A criminal group 1 passenger delegates only if the expected utility from doing so exceeds that of committing the crime himself, i.e., if

$$v - s_1 d_1 l_1 < v - s_2 d_2 l_1 - \delta.$$

Clearly, there is delegation in equilibrium only if δ is sufficiently small.

We assume that δ is distributed in the population according to a cdf G independent of v. For each value of s_1 and s_2, then, the fraction of group 1 members who commit a crime and do not delegate is

$$\left[1 - F_1\left(s_1 d_1 l_1\right)\right] \cdot \left[1 - G\left(l_1\left(s_1 d_1 - s_2 d_2\right)\right)\right],$$

and the fraction of group 2 members who commit a crime (delegated or not) is

$$\left[1 - F_2\left(s_2 d_2 l_2\right)\right] + G\left(l_1\left(s_1 d_1 - s_2 d_2\right)\right) \cdot \left[1 - F_1\left(s_2 d_2 l_1\right)\right].$$

Based on these crime rates, the hit rates in the groups 1 and 2 are, respectively,

$$H_1\left(s_1, s_2, d_1, d_2\right) = H_1\left(s_1, d_1\right) \cdot \left[1 - G\left(l_1\left(s_1 d_1 - s_2 d_2\right)\right)\right]$$

and

$$H_2\left(s_1, s_2, d_1, d_2\right) = H_2\left(s_2, d_2\right) + d_2 \cdot G\left(l_1\left(s_1 d_1 - s_2 d_2\right)\right) \cdot \left[1 - F_1\left(s_2 d_2 l_1\right)\right].$$

It can be verified that H_i is decreasing in s_i and increasing in s_j. Thus, plotting the two curves as a function of s_1 yields a similar picture to Figure 1. When the crime rates in the two groups are small, then

$$\begin{aligned} \frac{\partial}{\partial d_1} H_1\left(s_1, s_2, d_1, d_2\right) &\approx -s_1 d_1 l_1 f_1\left(s_1 d_1 l_1\right) \cdot \left[1 - G\left(l_1\left(s_1 d_1 - s_2 d_2\right)\right)\right] \\ \frac{\partial}{\partial d_1} H_2\left(s_1, s_2, d_1, d_2\right) &\approx 0. \end{aligned}$$

In equilibrium, $[1 - G(l_1(s_1 d_1 - s_2 d_2))]$ cannot be smaller than $d_2/(\beta d_1)$, for otherwise the expected utility from searching group 2 would exceed that from group 1, which cannot happen in equilibrium. This implies that $\frac{\partial}{\partial d_1} H_1(s_1, s_2, d_1, d_2) > 0$. Thus, as we increase d_1 by a small amount, the curve H_1 shifts down while the curve H_2 does not shift, as a first approximation. Therefore, Proposition 2 continues to hold in the case where characteristics are endogenous.

VII. Implications for Improving Airport Security. In this paper, we identified two channels for improving airport security: better targeting and better detection. Better targeting does not necessarily decrease the overall crime rate, although it will decrease crime in the group that is targeted. Targeting systems such as CAPPS are controversial from a civil liberties perspective. However, this paper shows that it is possible to test for intent-to-discriminate even in the presence of imperfections in monitoring. This finding may alleviate the concern that CAPPS surreptitiously introduces racial/ethnic bias in searching.

We also found that improved detection rates unambiguously decrease crime. In exploring this second channel, we showed that group-specific improvements in detection do not necessarily increase the number of searches for those groups. This suggests that improving cultural sensitivity of screeners should help not only in improving detection but also in reducing the burden of searches on innocent members of high crime groups. One way of improving cultural sensitivity might be to increase the cultural diversity of screeners.

FOOTNOTES

* Nicola Persico and Petra E. Todd are Associate Professors of Economics at the University of Pennsylvania. Their address is 3718 Locust Walk, Philadelphia, PA 19104. Partial support from the NSF is gratefully acknowledged.

1. CAPPS II was authorized by Congress in 2004 as part of the Transportation Safety Administration (TSA) Enabling Act. The precise algorithms and criteria used to calculate threat levels are classified.

2. See Green v. TSA, Case No. C04-763 Z, (W.D. Wash., filed 2004); see also Anderson v. Cornejo, 355 F.3d 1021 (7th Cir. 2004).

3. The result generalizes to the case of $n > 2$ groups. For other extensions, see Knowles and Ruben Hernandez-Murillo (2004), and Nicola Persico and Petra Todd (2004). Anwar and Fang (2004) develop a different test.

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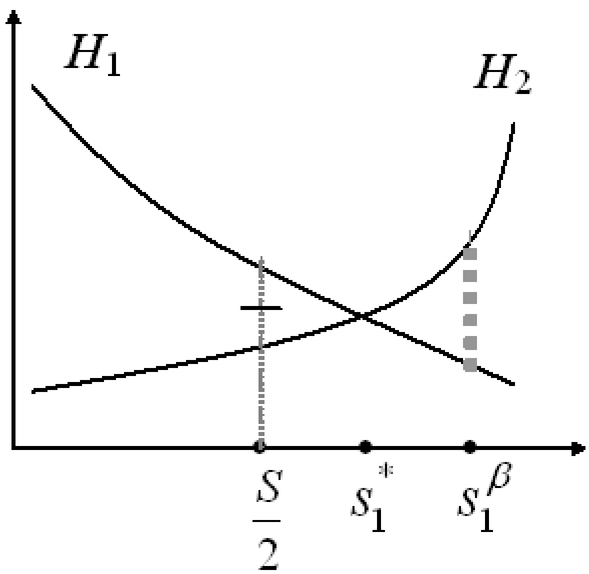

Figure 1: Hit rates as a function of search intensity.