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 tool to select passengers for screening which is currently being considered for implementation. 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. Passengers with elevated ratings are subject to searches and baggage inspections and may be questioned. Some other passengers are searched at random. Such profiling measures have been challenged in lawsuits alleging unlawful discrimination.

The KPT model is not directly applicable due to several differences between the airport screening process and the motor-vehicle search process. 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 distinct groups of passengers. CAPPS reveals information that screeners may otherwise not discern. However, CAPPS does not completely obviate the need for screener ability, because characteristics such as nervousness or hidden contraband are only detected by a perceptive screener. In fact, searches do not always detect violations; there is reportedly a 24-percent error rate in detecting weapons in baggage screening (see Sharyl Attkisson, 2002).

We extend the KPT model to incorporate the screeners’ limited ability to discern groups and to detect violations. We show that the “hit rates” 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 through improved capacity to distinguish groups. 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. The KPT 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 distinct groups of passengers. CAPPS reveals information that screeners may otherwise not discern. However, CAPPS does not completely obviate the need for screener ability, because characteristics such as nervousness or hidden contraband are only detected by a perceptive screener. In fact, searches do not always detect violations; there is reportedly a 24-percent error rate in detecting weapons in baggage screening (see Sharyl Attkisson, 2002).

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I. The Model

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A member of group $i$ derives value $v$ from...
committing a crime (regardless of whether he is found out), which is private information and passenger-specific; $v$ is distributed according to a cumulative distribution function $F_i$, with a density $f_i$ that is bounded above zero 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, which assumed $d_i/h_i$ for all $i$.

A criminal is apprehended only when he is searched and detected, in which case he incurs a loss $k_i$. 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 $h_1$ from apprehending a member of group 1, and of $h_2$ from apprehending a member of group 2. When the parameter $\beta$ exceeds 1, we say that the screeners are biased against group 1. The assumption of hit-rates maximization agrees with the behavior described 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

$$v - s_i(d_i\ell_i + k_i)$$

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 $1 - F_i(s_i d_i \ell_i)$. The hit rate (i.e., the probability that a search of a member of group $i$ is successful) is

$$H_i(s_i, d_i) = d_i [1 - F_i(s_i d_i \ell_i)].$$

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 $s_1$.

In equilibrium, screeners must receive the same expected utility from searching either group. Otherwise, screeners 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 $\beta$, if both groups are searched it must be true that

$$H_1(s_1^\beta, d_1) = H_2(s_2^\beta, d_2)$$

$$= H_2([S - s_1^\beta], d_2).$$

If $\beta = 1$ (i.e., there is no bias), the equilibrium is achieved at $s_1^\star$. If $\beta > 1$ the equilibrium is achieved at the point $s_1^\beta$ farther to the right. The disparity between the equilibrium hit rates, depicted by the thick dashed 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 discrim-

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 14th 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 $s_1^p > S/2 > s_2^p$, meaning that group 1 is searched disproportionately more in equilibrium.

III. Effect of CAPPS

Systems like CAPPS channel background information to the screener than (s)he cannot otherwise see. To the extent that the statistical model that underlies CAPPS can predict criminality, the CAPPS system allows the targeting of searches toward 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 $\frac{1}{2} [H_1(S/2, d_1) + H_2(S/2, d_2)]$, a level indicated by the long horizontal dash in Figure 1 for the case $d_1 = d_2 = 1$. 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. (On this perhaps surprising point, see Persico [2002] and Bernard E. Harcourt [2004]).

With regard to airport searches, we conjecture that dispensing with CAPPS would increase the crime rate because, 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 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. We are interested in the effect of increasing $d_i$ on the equilibrium search intensity of group 1. The latter decreases if the curve $H_1$ shifts downward (refer to Fig. 1). That curve shifts downward if

$$\frac{\partial H_1(s_1, d_1)}{\partial d_1} = \beta [1 - F_i(s_1 d_i \ell_i)] - s_1 d_i \ell_i \bar{f}_i(s_1 d_i \ell_i)]$$

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 above zero). 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 $d_1 = d_2 = d$, that is, detection ability is group-neutral. 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

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

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 $\ell_i$, which are unlikely to be observable to the researcher. 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 fewer searches of 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. We augment the model by allowing members of group 1 to, at a cost $\delta$, 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 $\delta$ 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 $\ell_1$. A criminal group-1 passenger delegates only if the expected utility from doing so exceeds that of committing the crime himself, that is, if

$$v - s_1 d_1 \ell_1 < v - s_2 d_2 \ell_1 - \delta.$$ 

Clearly, there is delegation in equilibrium only if $\delta$ is sufficiently small.

We assume that $\delta$ is distributed in the population according to a cumulative distribution function $G$ 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

$$[1 - F_1(s_1 d_1 \ell_1)][1 - G(\ell_1(s_1 d_1 - s_2 d_2))]$$

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

$$[1 - F_2(s_2 d_2 \ell_2)] + G(\ell_1(s_1 d_1 - s_2 d_2))$$

$$\times [1 - F_1(s_2 d_2 \ell_1)].$$

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

$$H_1(s_1, s_2, d_1, d_2) = H_1(s_1, d_1)$$

$$\times [1 - G(\ell_1(s_1 d_1 - s_2 d_2)))]$$

and

$$H_2(s_1, s_2, d_1, d_2) = H_2(s_2, d_2)$$

$$+ d_2 G(\ell_1(s_1 d_1 - s_2 d_2)) \times [1 - F_1(s_2 d_2 \ell_1)].$$

It can be verified that $H_1$ is decreasing in $s_1$ and increasing in $s_2$. 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

$$\frac{\partial}{\partial d_1} H_1(s_1, s_2, d_1, d_2) = -s_1 d_1 \ell_1 f_1(s_1 d_1 \ell_1)$$

$$\times [1 - G(\ell_1(s_1 d_1 - s_2 d_2)))]$$

$$\frac{\partial}{\partial d_1} H_2(s_1, s_2, d_1, d_2) = 0.$$ 

In equilibrium, $[1 - G(\ell_1(s_1 d_1 - s_2 d_2))]$ 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
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 study 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 have been controversial from a civil-liberties perspective. This paper shows that hit-rates tests for racial bias can be applied even in the presence of imperfections in monitoring. Such tests can serve as a check on whether, effectively, CAPPS 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.

REFERENCES


Attkisson, Sharyl. “Airport Security Fails The Test.” Posted online on (CBSNews.com), 1 July 2002 [copy on file with the authors].


