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Abstract

Robbery is a serious, widespread and sometimes violent crime resulting each year in costs to victims of several billion dollars. Data on the incidence of robbery reveals certain striking racial disparities. African Americans are more likely to be victims, arrestees and prisoners than are members of other demographic groups, and while black-on-white robberies are very common, white-on-black robberies are extremely rare. The disparities for robbery are also much greater than those for other crimes of acquisition. We develop a model of robbery that attempts to address these and other stylized facts. The key insight underlying the model is that robberies are typically interactions between strangers which involve a sequence of rapid decisions with severely limited information. Potential offenders must assess the likelihood of victim resistance, and victims must assess the likelihood that resistance will be met with violence. Racial disparities in the distribution of income can cause such probability assessments to be race-contingent, affecting crime rates as well as rates of resistance and violence. We argue that this model helps account for several empirical regularities that appear puzzling from the perspective of alternative theories of crime.

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1 Introduction

Robbery is a very serious crime, often involving violence, and resulting each year in aggregate costs to victims of several billion dollars.¹ It is also a crime that involves significant and persistent racial disparities. African-Americans are considerably more likely to be robbery victims, arrestees, and prisoners than either whites or Hispanics.² No other crimes except murder and possibly drug trafficking are nearly so concentrated among African-Americans. But robberies are about forty times as common as murders, and more state prison inmates are incarcerated for robbery than for any other index crime.³

Even more striking is the fact that while white-on-white, black-on-black, and black-on-white robberies are all very common, white-on-black robberies are extremely rare. Robberies with white victims and black offenders are more than twelve times as frequent as those with black victims and white offenders.⁴ Since white criminals are plentiful, the paucity of white-on-black robberies is puzzling. This phenomenon runs counter to some common beliefs about racism: if whites dislike blacks, or if law enforcement undervalues black safety, or if courts are reluctant to accept black testimony against whites, then white criminals should eagerly rob blacks. The abundance of black-on-white robbery is also somewhat surprising. Although the overwhelming majority of black robbers' victims would be white if robbers were sorted to victims completely randomly, most other

¹The direct cost to a victim of a robbery with injury is on average \$19,000; the cost of a robbery without injury is about \$2,000 (Miller, Cohen and Wiersma, 1996). These estimates include property damage, medical expenses, lost productivity, and intangible reduction in the quality of life. Updating to 2002, a year in which around half-a-million robberies occurred, implies costs to robbery victims of about \$5.4 billion. These estimates do not include the costs of precautions, fear, or heightened racial friction and segregation that robbery might cause.

²Relative to whites in 2002, African-Americans were 2.16 times as likely to be robbery victims in 2002, and 8.55 times as likely to be arrested for robbery. Relative to non-Hispanic whites, African-Americans were 16.1 times as likely to be incarcerated in a state prison for robbery. Relative to Hispanics, African Americans are 1.68 times as likely to be victims and 3.51 times as likely to be prisoners. In New York State in 1999, African-Americans were 2.85 times as likely to be arrested for robbery as Hispanics (Sources: National Criminal Victimization Survey 2002, Sourcebook of Criminal Justice Statistics, table 4.10; Harrison and Beck, 2004, table 15; New York State Division of Criminal Justice Statistics 2004, the Statistical Abstract, table 13, and American FactFinder.) The population base for arrests and prisoners is population over 18 (census); for victimization, population over 12 (NCVS).

³Around 151,000 individuals were incarcerated for robbery in 2002, of whom 91,000 were African-American (Harrison and Beck, 2004, table 15). 16.6% of African-Americans in prison have been convicted of robbery, more than any other index crime.

⁴Detailed evidence on these disparities is provided in Section 2 below.

crime seems to be concentrated within groups.⁵

What accounts for such systematic racial disparities? Answering this question is the chief goal of this paper. We argue that the key to understanding racial disparities in the prevalence of robberies is to recognize that they involve dynamic interactions among strangers under conditions of incomplete information. Victims of attempted robberies may choose to comply or resist, and offenders may respond to resistance by fleeing or attempting to force compliance through violence. Because members of different groups are drawn from different distributions of unobserved characteristics, they will be treated differently and will therefore face different incentives.⁶ Hence two individuals who share the same non-racial characteristics will exhibit systematic differences in equilibrium behavior. Specifically, the likelihood of victim resistance can depend on the perceived race of the offender, and hence make robbery itself more lucrative for members of groups who face less resistance. This interdependence of victim and offender conjectures makes robbery different from other crimes of acquisition (such as burglary and theft) and explains why blacks are more disproportionately involved with robbery than with these other crimes.⁷ Intimidation is no advantage for a burglar or thief, but it is for a robber. To the extent that whites find blacks intimidating, black criminals face incentives to eschew burglary and theft and concentrate on robbery.

More concretely, suppose that robbery victims believe that black offenders are more likely than white ones to use violence in the face of victim resistance. In this case, they will be less likely to resist black offenders relative to white ones. Other things equal, this results in crime being more lucrative for blacks relative to whites. Suppose further that potential offenders believe that black victims are more likely than white ones to resist an attempted robbery. Then offenders of all types will prefer white victims to black ones. The actual probabilities of violence (conditional on resistance) and resistance (conditional on being confronted) will be determined in equilibrium, and equilibrium beliefs must accurately reflect these objective probabilities. How might the beliefs described above arise in equilibrium *without any innate group differences in the propensity for violence*? This can happen if the probabilities of victim resistance and offender violence are correlated with such

⁵While 72% of the victims of black robbers were white, only 16% of the victims of black murderers were white, 26% of the victims of black rapists, and 53% of the victims of black assailants (Fox and Zawitz, 2004; NCVS 2002, table 42).

⁶By “unobserved” we mean characteristics that other participants in a robbery do not observe, not characteristics that econometricians do not usually observe. For example, the personal income of a robbery victim is typically unobservable to a potential offender.

⁷Regarding incarceration, for instance, the disproportion for blacks relative to non-Hispanic whites was 6.6 for burglary and 8.6 for theft, as compared with 16.1 for robbery.

characteristics as personal income or wealth, which are unobservable to the participants in a robbery, but which exhibit systematic and well-known differences across groups. For instance, if poorer offenders are more likely to use violence in an attempt to force compliance, and if poorer victims are more likely to resist robbery attempts, then racial income disparities can cause both victims and offenders to condition their actions on the perceived race of those with whom they are interacting. We show how this can account for the racial disparities in crime rates, as well as the enormous gap between black-on-white relative to white-on-black robberies.

Our theory also has empirical implications for rates of resistance and violence. We show that a uniform deterrence policy that makes robberies of all types less lucrative for offenders has the effect of lowering crime rates but of *increasing* the likelihood of violence conditional on resistance. The reason is that such policies lead to the disproportionate exit from the robber population of those potential offenders who are least prone to violence. Those who continue to rob are therefore more likely to be violent in the face of resistance. These predictions accord with the empirical record—while robberies overall declined by more than a half over the period 1993-2002, robberies involving injury declined at a much lower rate, and hence the proportion of robberies involving violence rose steadily.⁸

The model also implies systematic racial differences in rates of resistance and violence. For instance, we predict that offenders of all types will be *less* likely to resort to violence when facing resistance from white (rather than black) victims. This latter prediction is surprising, and follows from the fact that those potential robbers who confront only white victims are less prone to violence than those who confront victims of all types. The model also predicts that victims of all types will offer less resistance to black (relative to white) offenders. A first look at the data over the ten year period 1993-2002 provides some support for both of these predictions. On the other hand, we find that in the case of black-on-white robberies, the extent of resistance is higher, and the likelihood of violence lower than one would predict on the basis of the model. These findings are tentative, however, and a systematic empirical exploration is well beyond the scope of the present paper.

We begin in Section 2 with the legal definition of robbery and a further discussion of the empirical regularities that motivate this work. Section 3 contains a model of robbery which attempts to capture the essential features—sequential choice under incomplete information—described above. Section 4 uses the model to examine the effects of two kinds of law enforcement policies, deterrence and incapacitation, on robbery rates and on the incidence of resistance and violence. Section 5

⁸Section 4 contains further details on recent changes in robbery rates, violence and resistance.

extends the model to the case in which beliefs are conditioned on racial categorization, and shows how the racial disparities evident in the data can arise in equilibrium. Section 6 considers alternative hypotheses that have been advanced to account for racial disparities in the incidence of criminal behavior, and argues that they are inadequate in explaining both the extent and the nature of the disparity. Section 7 concludes.

2 Definitions and Evidence

In the United States, robbery is defined as “taking, or attempting to take, anything of value from the care, custody, or control of a person or persons by force or threat of force or violence and/or by putting the victim in fear” (Sourcebook, 2002, p. 570). Examples are muggings, hold-ups, and confrontations where one teenager scares another into giving up his coat. Unsuccessful attempts count as robberies.

Robbery is distinguished from other crimes of property acquisition by the use or threat of force. Burglary, for instance, involves entering a structure to take something without confronting a person, and theft involves activities like shoplifting where no personal confrontation occurs. Personal confrontation is a necessary element of robbery. Stealing a car with nobody in it is motor vehicle theft; stealing a car with someone in it (a carjacking) is robbery. Robbery differs from assault, another crime of personal confrontation, because its purpose is acquisition. Barroom brawls and domestic violence are assaults because offenders are not trying to acquire money or property from their victims.⁹

African-Americans are considerably more likely to be arrested and imprisoned for robbery relative to other groups. This does not necessarily imply that African-Americans *commit* robberies at a higher rate than members of other racial or ethnic groups since it cannot be reasonably assumed that the criminal justice system is free of bias. The consensus among criminologists who have studied the question for many years, however, is that African-Americans do commit robberies at considerably higher rates than whites or Hispanics. The relative disparities in offending probably approach the relative disparities in arrests or incarceration. A review article by Sampson and Lauritsen (1997) summarizes the consensus:

⁹A small number of robberies turn into murders when victims die. The classification of “murder” trumps the classification of “robbery.” For our purposes, these crimes should be considered robberies, but government agencies do not keep data in this fashion. The number of felony-murders, however, is small—less than half a percent of the number of robberies—and so we will ignore these crimes.

While limitations exist for both official and self-report data, it thus appears that race differences in offending as recorded in arrest reports and victimization surveys reflect real differences in the frequency and seriousness of delinquent acts.

Some of the most useful data on this question come from the National Criminal Victimization Survey (NCVS), a household survey that asks about crime experiences. Part of the survey asks crime victims about the people who committed crimes against them. Of victims of single offender robberies in 2002 who could identify the robber’s race, 46% said that the robber was black (NCVS 2002, table 40). In robberies with multiple offenders, 45% of victims who could identify the race of their robbers said they were all black; another 16% said the group robbing them were of mixed race (NCVS 2002, table 46). These proportions are almost as high as the proportions of African-Americans among robbery arrestees and prisoners. Table 1 provides more detail on victim identifications for single-offender robberies (NCVS 2002, table 42); standard errors are in parentheses.

Table 1: Victim Identification of Robbers, 2002 (Single Offender Robberies)
Proportion of total single offender robberies where identification was made

		Perceived race of robber			
		White	Black	Other	Total
Race of victim	White	0.399	0.331	0.104	0.734
	Black	0.027	0.226	0.013	0.266
	Total	0.426	0.457	0.117	1.000

The most striking feature of this table is the large difference between the number of black-on-white robberies and the number of white-on-black robberies.¹⁰ The latter are virtually non-existent. 2002 is not an anomaly in this regard; in 2001 the survey did not find any white victim of a black single-offender robbery. Similar patterns arise in the case of multiple offender robberies: in the 2002 survey over 30% of all such robberies involved a white victim and an all-black group of offenders,

¹⁰Standard errors are 0.054 (white-on-white), 0.052 (black-on-white), 0.017 (white-on-black) and 0.045 (black-on-black).

while none involved a black victim and an all-white group of offenders.¹¹ Our model addresses and accounts for this finding, as well as the disproportionate prevalence of blacks among the population of offenders.

3 A Model of Attempted Robbery

3.1 Preliminaries

The key elements of a robbery are personal confrontation (typically between strangers), the threat or use of force, and the attempt to obtain property. Such interactions involve a sequence of rapid decisions made by victims and offenders, and these decisions must be made under severe informational constraints. Under such conditions racial classification can influence the actions of both parties. Our model is an attempt to capture these effects.

When a potential robber is faced with an opportunity, he must decide whether or not to make the robbery attempt. If an attempt is made, the victim can either comply with the robber's demand or resist it. If faced with resistance, the robber can abandon the attempt and flee, or can try to force compliance through violence. When contemplating a robbery attempt, the perpetrator typically cannot know whether the victim will resist. Similarly, when contemplating resistance, the victim cannot know whether the robber will flee or attempt to force compliance. Resistance by the victim followed by an attempt at forced compliance is potentially very costly to both parties - both face the risk of serious injury, and the robber faces both an increased likelihood of arrest as well as more severe punishment conditional on arrest. The most desirable outcome from the robber's perspective is compliance by the victim. The most desirable outcome from the perspective of the potential victim is a decision by the potential robber not to make the robbery attempt in the first place. Conditional on a robbery attempt the victim's best response is to resist if she believes that the robber will flee, and to comply if she believes that the robber will use force. Conditional on victim resistance, the robber's best response may be to flee, or it may be to use violence in order to force compliance. And the payoffs to both robber and victim are somewhat lower in the case of a failed robbery attempt (when resistance is met with flight) than if no attempt had been made in

¹¹One problem with the NCVS, however, is that it observes very few actual robberies. Although it samples between 75,000 and 100,000 individuals a year, the total number of robberies observed annually ranges from just 165 (in 2002) to about 600 (in 1993). Accordingly, sampling errors for particular types of robbery (for instance black-on-black single offender robberies that are completed without violence) are large.

the first place.

These payoff considerations can be expressed in the form of a simple two-player game with three stages, as shown in Figure 1. At the first stage, the potential robber (player 1) decides whether or not to attempt to rob the potential victim (player 2). If there is no confrontation, payoffs of both players are normalized to equal zero. In this case each player retains her initial level of wealth. If the robber confronts the victim, the latter can either resist or comply with the robber's demand. If the victim complies, the payoffs are x_1 to the robber and $-x_2$ to the victim. If the victim resists the robber can then either flee or attempt to force compliance. If the robber flees, the payoffs are $-y_1$ to the robber and $-y_2$ to the victim. If the robber attempts to force compliance through violence, the payoffs are $-z_1$ to the robber and $-z_2$ to the victim.

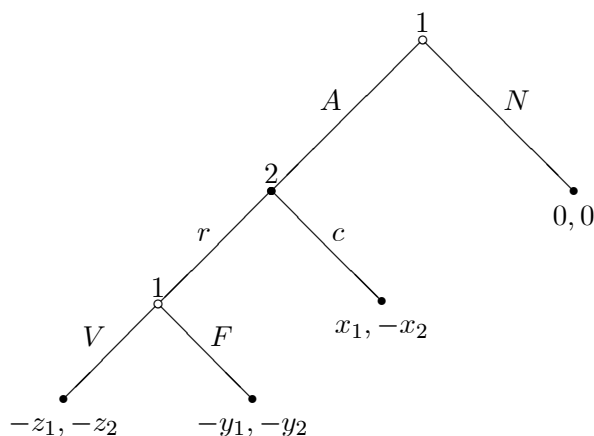


Figure 1: Dynamics of an Attempted Robbery

A key aspect of robbery that we wish to capture is robber uncertainty about the victim's likelihood of resistance, as well as victim uncertainty about the robber's propensity to respond violently to resistance. We allow for heterogeneity in preferences and incomplete information as follows. Suppose that each of the two players is drawn from a set of types $\Theta = [\theta_{\min}, \theta_{\max}]$, such that a player's type $\theta \in \Theta$ completely defines her preferences over all outcomes in the game. One interpretation of a player's type is her outside option or initial wealth level, although other interpretations are possible.

We intend θ to describe the characteristics of the robber and the victim that are unobservable during the attempted robbery. Given the potential robber's *observable* characteristics the distribution of robber types is commonly known and is described by the continuous distribution function

$F(\theta) : \Theta \rightarrow [0, 1]$. Similarly, given the victim's observable characteristics, the distribution of victim types is commonly known and is described by the continuous distribution function $G(\theta) : \Theta \rightarrow [0, 1]$. We allow for the possibility that F and G are identical, although in general (if robber and victim have different observable characteristics) these two functions will differ.¹²

The payoffs $x_i(\theta)$, $y_i(\theta)$, and $z_i(\theta)$ are all fully determined by the player's type and are assumed to be differentiable functions of θ . We assume that robbers of all types gain from a robbery attempt that is successful without violence, but lose from an unsuccessful attempt. This is relative to the zero-payoff baseline in which no robbery attempt is made. Furthermore, we assume that victims of all types rank the four possible outcomes in the same order: from the victim's point of view, violent robberies are worse than successful non-violent ones, which in turn are worse than unsuccessful robbery attempts. Hence a victim who is certain that resistance will be met with flight will resist, and one who is certain that resistance will be met with violence will comply. Best of all is the outcome in which no attempt at robbery is made in the first place. These considerations imply the following:

Assumption 1. For all $\theta \in \Theta$, $x_1(\theta) > 0$, $y_1(\theta) > 0$, and $z_2(\theta) > x_2(\theta) > y_2(\theta) > 0$.

In addition, we assume that victims of higher type lose less when successfully robbed, but lose more when subjected to violence. This is motivated by the interpretation of θ as an outside option or initial wealth level. The rationale is that the wealth transfer that takes place during a successful robbery is a smaller share of initial wealth for higher types, while the willingness-to-pay to avoid injury is greater for wealthier individuals. Formally:

Assumption 2. For all $\theta \in \Theta$, $x'_2(\theta) < 0 < z'_2(\theta)$.

Next, we assume that robbers with higher θ incur higher costs from a violent outcome as well as from an unsuccessful robbery attempt, and the former costs rise faster than the latter. Wealthier robbers have more to lose from the harsher penalties or injuries that can result from a violent outcome, and these costs rise with wealth faster than the relatively minor costs associated with an unsuccessful robbery attempt. The payoffs of victims vary with type in exactly the same way: wealthier victims incur greater costs from violent outcomes as well as from failed robbery attempts, and the former costs rise with wealth more rapidly than the latter costs. This implies the following:

¹²In section 5 we explicitly introduce race as an observable characteristic and explore the implications of this for equilibrium behavior. More generally, such attributes as age, weight, gender, manner of dress and speaking, presence of eyeglasses or facial scars, or visible possession of a weapon could all be observable attributes which affect beliefs.

Assumption 3. For all $\theta \in \Theta$, and for $j = 1, 2$, $z'_j(\theta) > y'_j(\theta)$.

Finally, we assume that robbers with very low wealth levels prefer to respond violently when faced with resistance, while those with higher wealth levels prefer to flee. Furthermore, individuals with sufficiently low wealth prefer to attempt robbery even if they are certain of resistance. The rationale is that poorer robbers have more to gain from the completion of the robbery, and hence the higher probability of capture (and the more severe penalties conditional on capture) that violence entails are less of a disincentive. Hence we have:

Assumption 4. $z_1(\theta_{\min}) < 0$ and $z_1(\theta_{\max}) > y_1(\theta_{\max})$.

Assumptions 1-4 together imply that for any given beliefs of the victim regarding the probability with which resistance will be met with violence, lower wealth victims will be more likely to resist relative to higher wealth victims. They also imply that for any given robber beliefs about the probability of victim resistance, lower wealth individuals will be more likely to attempt robbery.

We have motivated our discussion of types by interpreting θ as wealth or income—an unobservable variable that reduces a robber’s willingness to use violence and increases a victim’s expected losses from a violent encounter. Wealth, of course, is not the only variable that has this property. For instance, unobserved psychological and moral propensities, real or imagined, clearly play a role in how people react in stressful situations. It is probably most appropriate to think of θ as a latent variable that is a function of both wealth and a set of psychological variables.¹³

The game tree depicted in Figure 1, together with the common priors $F(\theta)$ and $G(\theta)$, over player types and the functions $x_i(\theta)$, $y_i(\theta)$ and $z_i(\theta)$ together define an extensive-form Bayesian game Γ . We next characterize the Perfect Bayesian Equilibria of this game.

3.2 Equilibrium

Consider a victim who has been confronted by a robber and believes that resistance will be met with violence with probability λ . In this case the victim will comply if her type θ is such that

$$x_2(\theta) < \lambda z_2(\theta) + (1 - \lambda) y_2(\theta) \tag{1}$$

¹³Empirical considerations also require this richer interpretation of θ . Hispanics have about the same distribution of income and wealth as blacks, but are arrested for far fewer robberies. Explaining why the black distribution of θ has come to be different from the Hispanic distribution is a topic for future research.

and resist if the inequality is reversed. Since x_2 is strictly decreasing and both y_2 and z_2 are increasing, there will exist some threshold type $\tilde{\theta}(\lambda)$ such that victims will comply if their wealth exceeds $\tilde{\theta}(\lambda)$ and resist if it lies below it. The probability that a robber will meet resistance is then simply $G(\tilde{\theta})$. The threshold $\tilde{\theta}$ is itself strictly decreasing in λ ; the greater the expectation of violence, the smaller the set of victims who resist.

Now suppose that potential robbers believe that a proportion μ of victims will resist if confronted. In this case an individual of type θ will attempt robbery if

$$(1 - \mu) x_1(\theta) > \mu \min \{y_1(\theta), z_1(\theta)\}, \quad (2)$$

and refrain from doing so if the inequality is reversed. Since $z_1(\theta_{\min}) < 0$ and $x_1 > 0$ for all θ , individuals who are of sufficiently low type will attempt robbery. Furthermore, since $\min \{y_1(\theta), z_1(\theta)\}$ is increasing and $x_1(\theta)$ is decreasing, there exists some type $\hat{\theta} > \theta_{\min}$ such that all types below $\hat{\theta}$ attempt robbery and all types above $\hat{\theta}$ do not. The threshold $\hat{\theta}$ is strictly decreasing in μ . Of the types who attempt robbery, a subset will use violence if they meet with resistance. Let $\bar{\theta} \in (\theta_{\min}, \theta_{\max})$ denote the unique solution to the equation $y_1(\theta) = z_1(\theta)$.¹⁴ Then the proportion of robbers who are prepared to use violence is given by $F(\bar{\theta})/F(\hat{\theta})$ if $\hat{\theta} \geq \bar{\theta}$ and 1 otherwise.

In equilibrium, the beliefs of both robbers and victims must be consistent with the strategies adopted by the players, namely the mappings from types to actions. Hence equilibrium beliefs (λ^*, μ^*) must satisfy

$$\lambda^* = \min \left\{ \frac{F(\bar{\theta})}{F(\hat{\theta}(\mu^*))}, 1 \right\} \quad (3)$$

and

$$\mu^* = G(\tilde{\theta}(\lambda^*)). \quad (4)$$

Given our assumptions, the following holds (see the appendix for proofs of all formal results):

Proposition 1. Γ has a unique equilibrium (λ^*, μ^*) , and $\lambda^* \in (0, 1)$.

Since $\lambda^* \in (0, 1)$ in equilibrium, we can rewrite (3) as simply

$$\lambda^* = \frac{F(\bar{\theta})}{F(\hat{\theta}(\mu^*))}, \quad (5)$$

and combine this with (4) to get the following equilibrium condition:

$$\lambda^* F \left(\hat{\theta} \left(G \left(\tilde{\theta}(\lambda^*) \right) \right) \right) = F(\bar{\theta}) \quad (6)$$

¹⁴Uniqueness and interiority of $\bar{\theta}$ follows from assumptions 3 and 4 above.

In equilibrium, some types attempt robbery while others do not. The set of types who attempt robbery include some who flee when met with resistance, and also some who resort to violence. Hence there are three types of crime that can arise with positive probability: (i) nonviolent robberies, (ii) violent robberies, and (iii) failed attempted robberies. The rates at which these occur depend on the type distribution in the population and the manner in which types are related to payoffs through the functions x_i , y_i , and z_i . Given the payoff and distribution functions, rates of crime, violence and resistance are *uniquely* determined.

3.3 Crime Rates

Given the equilibrium values (λ^*, μ^*) , determined jointly by the conditions (4) and (5), the overall crime rate (aggregating the three types of crimes) is given by $\gamma^* = F(\hat{\theta}(\mu^*))$. The proportion of robbery attempts that are successful without violence is simply $1 - \mu^*$. The proportion of robbery attempts that fail are $\mu^*(1 - \lambda^*)$, and the proportion that end in violence are $\mu^*\lambda^*$.

Many of the equilibrium parameters can be recovered directly from empirical data—assuming that the distribution from which robbers are drawn is the same in all encounters, as is the distribution from which victims are drawn.¹⁵ For instance, the NCVS shows the following as the outcomes of all single-offender robberies in 2002:

Table 2: Composition of Robberies, 2002

	Completed	Not completed
With injury	25.8%	13.0%
Without injury	41.7%	19.4%

Here “completed” means robberies where something of value was acquired from the victim. The bottom left cell, “completed, without injury” is the proportion of robbery attempts successful without violence, $1 - \mu^*$. Hence we estimate

$$\mu^* = 0.583$$

for all robberies in 2002 (under our very strong assumption of no relevant differences in observable characteristics). The bottom right cell, “not completed, without injury,” is the proportion of failed

¹⁵These assumptions will be relaxed in Section 5 below, where we allow for race-contingent differences in beliefs.

robbery attempts, $\mu^*(1 - \lambda^*)$. Hence we can estimate

$$\mu^*(1 - \lambda^*) = 0.194$$

and so

$$\lambda^* = 0.667$$

Standard errors for our estimates of μ^* and λ^* are 0.056 and 0.069 respectively. Since we do not know how many possible encounters do not occur because the potential robber decides not to initiate a robbery attempt, we have little empirical information on γ^* .

This method has another weakness, in addition to the assumption of the irrelevance of observed characteristics. Some robberies do not conform to the game-theoretic model we have been discussing. Sometimes robbers will simply strike their victims first and forcibly remove valuables, instead of making demands and letting victims decide whether to comply. These crimes will appear in the upper left-hand corner, “completed, with violence,” along with crimes where the robbery follows our model. If we were able to purge strike-first robberies from the data, our estimates of μ^* and λ^* would both decrease.

4 Deterrence and Incapacitation

Many discussions of criminal justice policy revolve around the relative effectiveness of deterrence and incapacitation, broadly defined. Deterrence policies attempt to make crime less attractive to all types of potential criminals by increasing the expected punishment that follows commission of a crime. Incapacitation policies attempt to alter the distribution of types in the population without changing the propensity of any given type to commit crime. Broadly construed, incapacitation policies thus include not only imprisonment but also education, rehabilitation, the encouragement of religion and morality, and possibly access to abortion.

In our model, incapacitation policies alter the distribution of robber types, while deterrence policies change the robbers’ payoff functions. Since our model includes three different kinds of robberies (failed, successful without violence, and successful with violence), there are at least three different kinds of deterrence policy. In particular, we are interested in the manner in which changes in the functions x_1 , y_1 and z_1 affect the equilibrium values of λ^* and μ^* . Three types of changes are possible: (i) harsher penalties from violence, which we interpret as an upward shift in the $z_1(\theta)$ function, (ii) smaller expected rewards for successful robberies, which we interpret as a downward shift in $x_1(\theta)$, and (iii) harsher penalties for failed attempts at robbery, or a rise in $y_1(\theta)$.

Proposition 2. *Harsher penalties for violence result in a declines in λ^* and γ^* , and a rise in μ^* . Smaller rewards for successful robberies, or harsher penalties for failed robbery attempts, result in a rise in λ^* , and declines in μ^* and γ^* .*

As might be expected, all deterrence policies result in a lowering of the crime rate γ^* . The effects on the prevalence of resistance and violence depend, however, on the details of the policy. Harsher penalties for violence reduce the equilibrium likelihood that resistance will be met with violence, and result therefore in greater resistance. While the overall proportion of robberies ending in violence is indeterminate (since resistance is higher) the proportion that are successful without violence falls, as does the overall crime rate.

Smaller rewards for successful robberies could arise either from a higher likelihood of subsequent apprehension, harsher penalties conditional on apprehension, or a decline in the amount of cash and other valuables held by potential victims. While this deterrence policy also results in a lower crime rate, the probability of violence contingent on resistance rises, and the extent of resistance accordingly declines. The reason for this is that the decline in crime rate results from the exit of robbers with higher θ , who are also less prone to violence; the robbers who remain are lower θ types who are more likely to be violent. Lower resistance implies that a greater proportion of attempted robberies are successful, and a greater proportion of resisted robberies end in violence. Higher penalties for failed robbery attempts have exactly the same effect.

In practice, any given policy that changes penalties or rewards will simultaneously affect all three functions x_1 , y_1 , and z_1 . Proposition 2 can be used collectively to determine the direction of these effects, although in some cases unambiguous predictions may not be possible. One case in which unambiguous predictions can be made is that in which expected penalties for all kinds of robbery increase by the same amount. We say that a *uniform deterrence policy* is imposed if, for all θ , $x_1(\theta)$ decreases by some amount $k > 0$, and $y_1(\theta)$ and $z_1(\theta)$ increase by k . Qualitatively, uniform deterrence increases look like increases in penalties for failed robberies:

Proposition 3. *A uniform deterrence policy results in a rise in λ^* , and declines in μ^* and γ^* .*

These results yield empirical predictions. A uniform deterrence increase or an increase in the penalties for failed robberies should raise the proportion of robberies that are successful and nonviolent $(1 - \mu^*)$, and cut the proportion of failed robberies $\mu^*(1 - \lambda^*)$. The effect on violent robberies $\mu^*\lambda^*$ is ambiguous. On the other hand, harsher penalties for violent robberies should reduce the proportion of successful nonviolent robberies and raise the proportion of failed robberies.

Table 3: Changes in Robberies by Kind 1993-2002 (1993 = 100)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Completed, with injury	100	119	87	115	127	75	93	59	72	66
Failed, with injury	100	114	63	73	80	79	64	75	97	65
Completed, no injury	100	116	129	122	83	121	100	93	61	52
Failed, no injury	100	90	83	91	66	54	49	36	37	22
Total	100	107	99	105	84	85	77	65	58	45

Since the overall incidence of robbery fell dramatically during the 1990s, these results let us begin to assess what sort of impact deterrence policies may have had. Table 3 shows the changes in each of the four classes of single-offender robbery between 1993 and 2002, a period over which the aggregate decline was 55%. Several patterns are evident in the table. Robberies involving injuries declined less than robberies overall, so the share of violent robberies in total robberies increased over this period. The sharpest declines occurred in failed robbery attempts (without injury), suggesting that conditional on resistance, the incidence of violence rose. Successful robberies without injury declined somewhat less than robberies overall, suggesting that rates of resistance fell slightly over the period. Direct computation of rates of resistance and violence confirms that there was a steady increase in λ , with a modest (but insignificant) decline in μ over this period (Table 4).¹⁶ This trend is not compatible with an *exclusive* reliance on harsher penalties for violent crimes, but it is consistent with the other kinds of deterrence measures, including a uniform deterrence policy.

Table 4: Changes in rates of violence and resistance, 1993-2002

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
λ	0.431	0.497	0.416	0.456	0.561	0.516	0.560	0.578	0.625	0.694
μ	0.627	0.597	0.514	0.567	0.635	0.469	0.517	0.467	0.606	0.570

Finally, consider the effects of incapacitation, which we interpret as changes in distribution of robber types.¹⁷

¹⁶Standard errors range from 0.030 to 0.048 (for estimates of λ) and from 0.024 to 0.042 (for estimates of μ).

¹⁷Such a shift could also be induced by an increase in the overall prosperity of the population from which potential robbers are drawn.

Proposition 4. *A shift to the right in the type distribution of potential robbers (a decline in $F(\theta)$ at every θ) results in a decline in γ^* .*

In general we cannot tell how λ^* and μ^* will react to a change in the distribution of criminal types without specifying more precisely how the distribution of types changes. However, a policy that disproportionately incapacitates potential robbers with low θ will lower λ^* and raise μ^* . To see this, suppose we start at some distribution F and move to a new distribution H that stochastically dominates F . In other words, $H(\theta)/F(\theta) \leq 1$. If the movement from F to H disproportionately incapacitates the potential robbers with the smallest θ , then $H(\theta)/F(\theta)$ will be an increasing function. We say that incapacitation is *directed at the violent* if $H(\theta)/F(\theta) \leq 1$ and is increasing for all $\theta \geq \bar{\theta}$. For future reference, when $H(\theta)$ and $F(\theta)$ are such that H that stochastically dominates F and $H(\theta)/F(\theta)$ is increasing, we shall say that $F(\theta)$ is *strongly tougher* than $H(\theta)$. Then we have

Proposition 5. *A policy of incapacitation directed at the violent decreases λ^* and raises μ^* .*

Intuitively, reducing the proportion of robbers who are most inclined to violence makes the average remaining robber less violent, and so makes victims more inclined to resist. Since λ in fact rose steadily over the period 1993-2002, the decline in robbery rates over this period cannot be attributed simply to the incarceration of the most violent criminals.

Our model also allows us to see how changes in the incentives and characteristics of victims affect the number and kind of robberies. Emergency medical systems, and insurance and victim compensation policies, for instance, can change victims' expected payoffs. Changes in prosperity can also change the distribution of victim types. For brevity, we can consider changes in payoff functions and changes in distribution functions together:

Proposition 6. *An increase in the expected cost to victims of violence (higher $z_2(\theta)$ for all θ) or a shift to the right in the distribution of victim types (lower $G(\theta)$ for all θ), reduces μ^* and λ^* , and raises γ^* .*

Both of these changes, then, lead to a smaller proportion of violent robberies, and a higher proportion of successful nonviolent robberies. The prediction for failed robberies is ambiguous.

We can test these predictions by comparing robberies with firearms to robberies where no weapon is used (based on victim reports). We ignore robberies with other kinds of weapons. For

victims, firearms make the consequences of violence much worse, and so Proposition 6 applies. In the 2002 NCVS (table 66), 48.1% of robberies where the robber had no weapons ended up with the victim injured, compared with 20.7% of robberies where the robber had a firearm. This is very much in accord with Proposition 6. Our estimate of μ^* is 0.675 (standard error 0.063) with no weapons, and 0.370 (standard error 0.080) with a firearm. Victims are much less likely to resist when the robber has a firearm. Somewhat less intuitively, the presence of a firearm makes λ^* fall from 0.713 (standard error 0.073) to 0.559 (standard error 0.133) although this difference is not significant at conventional levels. Our model thus captures the essential features of how these two varieties of robbery differ. Firearms have two distinct effects: they raise the costs of resistance (thus lowering the incidence of resistance) and they induce non-violent robbers to enter the business (thus lowering the incidence of violence conditional on resistance).

5 Explaining Racial Disparities

The model so far has assumed, in effect, that all robbers and victims have the same observable characteristics. In order to address and account for the kind of racial disparities identified in the introduction, this assumption needs to be relaxed. We do so as follows. Suppose that each individual belongs to one of two identifiable groups, blacks and whites, and that the groups differ with respect to their type distributions. Let $F_b(\theta)$ and $F_w(\theta)$ denote the distribution functions for robbers in the two groups respectively. Let $G_b(\theta)$ and $G_w(\theta)$ denote the distribution functions for victims in the two groups respectively. Suppose that all other functions x_i , y_i and z_i are identical across groups, which implies also that the threshold $\bar{\theta}$ and the functions $\hat{\theta}(\mu)$ and $\tilde{\theta}(\lambda)$ are the same.

We know from Proposition 1 that for any given interaction (once the race of both victim and offender have been observed), equilibrium behavior is uniquely determined.¹⁸ Behavior in equilibrium will generally be *race-contingent*. For instance, a victim's decision to resist may depend on the race of the perpetrator, since this may provide information about the probability with which

¹⁸Uniqueness of equilibrium is unusual in models of statistical discrimination descended from Arrow(1973). Since groups are typically assumed to be *ex-ante* identical, the existence of an equilibrium with discrimination implies the existence of another equilibrium in which the positions of the groups are interchanged; see, for instance, Coate and Loury (1993), Chaudhuri and Sethi (2003), Fryer (2004) and Moro and Norman (2004). In our model, while groups are *ex-ante* identical with respect to their preferences, they differ with respect to their respective income distributions, and this is enough to induce differences in behavior despite the uniqueness of equilibrium.

resistance is met with violence. This latter probability may itself depend on the race of the victim, if a robber's decision to confront a victim is sensitive to the victim's race.

To allow for all these effects, let λ_{ij} denote the victim's estimate of the probability with which resistance will be met with violence when the perpetrator belongs to group i and the victim to group j . Similarly, let μ_{ij} denote the robber's perception of the probability with which the victim will resist when the perpetrator belongs to group i and the victim to group j . The following equilibrium conditions now need to be satisfied for each offender type $i \in \{b, w\}$ and each victim type $j \in \{b, w\}$:

$$\lambda_{ij}^* = \frac{F_i(\bar{\theta})}{F_i(\hat{\theta}(\mu_{ij}^*))} \quad (7)$$

and

$$\mu_{ij}^* = G_j(\tilde{\theta}(\lambda_{ij}^*)). \quad (8)$$

These can be consolidated as follows:

$$\lambda_{ij}^* F_i(\hat{\theta}(G_j(\tilde{\theta}(\lambda_{ij}^*)))) = F_i(\bar{\theta}) \quad (9)$$

Let $\gamma_{ij}^* \equiv F_i(\hat{\theta}(\mu_{ij}^*))$ denote the crime rate when the perpetrator belongs to group i and the victim to group j .

The following result establishes that if the white income distribution stochastically dominates the black income distribution among the population of potential robbers, then blacks will have higher crime rates than whites against each victim group. Furthermore, if the black income distribution is strongly tougher than the white distribution, then white offenders will be resisted more frequently in equilibrium, and are less likely to resort to violence conditional on resistance, regardless of whether the victim is black or white.¹⁹

Proposition 7. *Suppose that for all $\theta \in \Theta$, $F_b(\theta) > F_w(\theta)$. Then for each $j \in \{b, w\}$, $\gamma_{bj}^* > \gamma_{wj}^*$. If, in addition, $F_b(\theta)$ is strongly tougher than $F_w(\theta)$, then $\lambda_{bj}^* > \lambda_{wj}^*$ and $\mu_{bj}^* < \mu_{wj}^*$ for each $j \in \{b, w\}$.*

Hence black crime rates will be uniformly higher than white crime rates against both black and white victims if whites are more affluent than blacks as a group. Note that this effect occurs despite the fact that successfully robbing whites is no more lucrative than successfully robbing blacks: we have assumed that robber payoffs are independent of victim types. The reason for the higher crime

¹⁹Empirically, the black income distribution is indeed strongly tougher than the white.

rates is more subtle and can be understood intuitively as follows. Suppose crime rates were uniform across race. Then blacks would face lower resistance from victims of all groups since, relative to whites, a greater proportion of those attempting robbery would be willing to use violence. This follows directly from the hypothesis that the white income distribution stochastically dominates the black income distribution. Lower resistance makes crime more lucrative, resulting in higher black crime rates. Note that in equilibrium, it need not be the case that blacks in fact face lower resistance or that a greater proportion of black offenders are prepared to use violence. Since the set of types who choose robbery in the black population is larger than the set of types who choose robbery in the white population, it is entirely possible that a greater proportion of black robbers are in fact non-violent in equilibrium.

Next consider how rates of crime, resistance and violence vary with the race of the victim, holding fixed that of the robber:

Proposition 8. *Suppose that for all $\theta \in \Theta$, $G_b(\theta) > G_w(\theta)$. Then for each $i \in \{b, w\}$, $\gamma_{ib}^* < \gamma_{iw}^*$, $\lambda_{ib}^* > \lambda_{iw}^*$ and $\mu_{ib}^* > \mu_{iw}^*$.*

Hence all robbers in both groups exhibit a preference for white over black victims. The probability of violence conditional on resistance is greater for black victims relative to white. This is because the pool of offenders willing to confront white victims is larger and hence contains a greater share of non-violent types. Despite the fact that white victims are less likely to face violence conditional on resistance, the model predicts that they resist at lower rates than black victims. Hence the effect on resistance rates of the fact that whites are richer as a group outweighs the effect of the fact that they face a less violent population of robbers in equilibrium.

These theoretical results have certain clear empirical implications for rates of crime, resistance and violence. While a systematic empirical analysis is well beyond the scope of this paper, we can provide a tentative assessment of some of these implications using NCVS data.

5.1 Disparities in Crime Rates

Taken together, Propositions 7-8 imply that if the white income distribution stochastically dominates the black income distribution in both robber and victim populations, then $\gamma_{wb}^* < \gamma_{ww}^* < \gamma_{bw}^*$ and $\gamma_{wb}^* < \gamma_{bb}^* < \gamma_{bw}^*$. These conditions can be combined as follows:

$$\gamma_{wb}^* < \min\{\gamma_{ww}^*, \gamma_{bb}^*\} \leq \max\{\gamma_{ww}^*, \gamma_{bb}^*\} < \gamma_{bw}^* \quad (10)$$

Does the empirical evidence support the ordering of crime rates implied by (10)? Since we do not observe the denominators of crime rates directly, we need to make some assumptions and calculations to see whether the data roughly support (10). Residential segregation in metropolitan areas implies that encounters are biased toward within-group members, and any reasonable estimate of the crime rates γ_{bb} and γ_{ww} needs to take this into account. Assuming that robbers confront only individuals in their own neighborhoods, and encounter potential victims randomly within neighborhoods, we can use data on segregation from the Lewis Mumford Center (2002) to calculate the probability of various kinds of encounters, and then use table 1 to infer crime rates. This procedure has two drawbacks: it ignores robberies outside metropolitan areas, and the Mumford Center uses different racial classifications from those the NCVS uses. But the robbery rate outside metropolitan areas is quite low, and we can use census data on racial and ethnic cross-tabulations to make the Mumford Center data roughly congruent with the NCVS. The resulting relative crime rates (after normalizing the white-on-white rate to equal one) are:

$$\gamma_{wb} = 0.39, \quad \gamma_{ww} = 1.00, \quad \gamma_{bb} = 4.16, \quad \gamma_{bw} = 8.74.$$

The rankings of crime rates are fully in accordance with (10), and the black-on-white crime rate is an order of magnitude higher than the white-on-black crime rate.²⁰

5.2 Disparities in Resistance and Violence

Propositions 7-8 also make sharp predictions about rates of violence and resistance. Holding constant the race of the offender, a white victim faces a *lower* probability that resistance will be met with violence. Despite this, white victims resist with lower frequency. And holding constant the race of the victim, black offenders are more likely to resort to violence conditional on resistance, and are less likely to face resistance in the first place. How well do these predictions accord with the evidence? NCVS data for single-offender robberies can be used to address this question. Since white-on-black robberies are so rare, we examine the validity of our predictions for the remaining three categories of crime.

²⁰Since any assumptions about matching imply that the number of times a black meets a white is the same as the number of times a white meets a black, the relationship between γ_{bw}^* and γ_{wb}^* remains the same no matter how blacks and whites are matched.

Table 5: Rates of violence by race of victim, 1993-2002

	1993	1994*	1995*	1996	1997	1998	1999*	2000	2001	2002
λ_{bw}	0.322	0.373	0.242	0.296	0.563	0.480	0.324	0.694	0.754	0.776
λ_{bb}	0.461	0.646	0.652	0.535	0.727	0.518	0.659	0.698	0.522	0.699

One of the less intuitive predictions of the model is that relative to black victims, white victims face a smaller likelihood of violence conditional on resistance: $\lambda_{bw}^* < \lambda_{bb}^*$. Aggregating data for the period 1993-2002, we obtain the estimates $\lambda_{bw} = 0.448$ (standard error 0.029) and $\lambda_{bb} = 0.614$ (standard error 0.037), confirming that black victims do, in fact face a considerably higher likelihood of violence when they choose to resist black offenders. This difference is statistically significant. Table 5 contains the disaggregated data, which shows that despite considerable variation over time in rates of violence, the predicted inequality is satisfied for eight of the ten years in the sample. For three of these years (denoted by an asterisk) the difference is statistically significant at the 5% level. Moreover, for the two years in which the inequality is not satisfied the difference is insignificant.

Turning to the likelihood of resistance, the model implies that white victims will resist with greater likelihood when faced with a white (rather than black) offender: $\mu_{ww}^* > \mu_{bw}^*$. Aggregate estimates of rates of resistance for the period 1993-2002 are $\mu_{ww} = 0.618$ (standard error 0.019) and $\mu_{bw} = 0.553$ (standard error 0.023), which is consistent with this prediction. This difference is statistically significant. The disaggregated data is shown in Table 6: the inequality holds in seven of the ten years in the sample, although none of the individual year differences is significant.

Table 6: Rates of resistance by race of offender, 1993-2002

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
μ_{bw}	0.561	0.621	0.570	0.523	0.592	0.512	0.625	0.442	0.549	0.411
μ_{ww}	0.724	0.699	0.491	0.666	0.703	0.466	0.499	0.563	0.674	0.673

Some predictions of the model, however, accord less well with the data. The model predicts (under the somewhat stronger assumptions of Proposition 7), that white victims will face a higher likelihood of violence from black (relative to white) offenders: $\lambda_{bw}^* > \lambda_{ww}^*$. This appears not to be the case when we look at the period 1993-2002, for which we find $\lambda_{ww} = 0.464 > 0.448 = \lambda_{bw}$ in the aggregate. In other words, white victims appear to face a smaller likelihood of violence from black (relative to white) offenders than our model predicts. However, this difference is not statistically

significant (standard errors are 0.024 and 0.029 for estimates of λ_{ww} and λ_{bw} respectively). In addition, the model predicts that black offenders will face greater resistance from black victims than they face from white victims: $\mu_{bw}^* < \mu_{bb}^*$. This too appears not to hold in the aggregate for the period in question, where we find $\mu_{bb} = 0.479 < 0.550 = \mu_{bw}$. This difference is statistically significant (standard errors are 0.027 and 0.023 for estimates of μ_{bb} and μ_{bw} respectively). In other words, black offenders face somewhat more resistance from white victims than one would predict on the basis of the model. It is conceivable that the higher resistance by white victims (relative to the model’s predictions) is simply a rational response to the lower likelihood of violence they face from black offenders. This leaves open the question of why black offenders are less violent than white offenders in interactions with white victims, an empirical puzzle that we hope to address in future work.

To summarize, the model accounts for the racial disparity in robberies, and in particular the enormous gap between black-on-white and white-on-black robbery rates. It also makes a number of predictions about racial differences in rates of resistance and violence which can be tested against the empirical record. A preliminary look at the data suggests that some (but not all) of the predicted patterns appear to arise. Until a systematic empirical investigation is undertaken, however, these empirical claims must be considered highly tentative.

We turn next to a discussion of alternative theories which have been advanced to account for racial disparities in crime, and argue that they do not adequately capture the stylized facts that motivate our analysis.

6 Alternative Explanations

Quite a few theories have been advanced to explain the racial disparity in robbery rates. There are also “common-sense” folk explanations. In this section we will review some of the more popular of these theories, and show why they are inadequate. Sampson and Lauritsen (1997) provide a more detailed critique of many of these theories. While the various arguments presented here can account to some degree for the racial disparities in overall crime perpetration, none are able to address the striking fact that black-on-white robbery rates are vastly greater than white-on-black robbery rates. Furthermore, since these are theories of crime in general rather than robbery in particular. Hence they cannot account for the rise in the proportion of robberies with injury as overall robbery rates have fallen, and cannot address racial disparities in the likelihood of resistance

and violence.

6.1 Characteristics

The most popular way to explain racial disparities in crime is to point to some particular characteristic, assert that this characteristic causes a disproportionate propensity to engage in crime, and show that African-Americans are more likely than whites to have this characteristic. Examples of characteristics that might be used in this way are: having grown up without a father present, being poor, being poorly educated, having lower scores on measures of “intelligence”, and owning a gun. In this view, characteristics are the link between race and crime: conditional on having one or more of them, blacks should be no more or less likely to commit crime than whites or Hispanics.²¹

These explanations fail because it is impossible to explain the racial disparity in robbery unless you can explain why blacks are more likely to commit robbery *conditional on these characteristics*. Robbery arrests are far more concentrated on African-Americans than are any of these characteristics. As noted in the introduction, blacks are over *eight* times as likely as whites to be arrested for robbery. Yet black children are only 2.56 times as likely as white to live with a single parent (Statistical Abstract 2000, table 70), blacks between 18 and 35 are only 1.90 times as likely to be poor as whites of similar age, and blacks are *less* likely to own guns than whites, both unconditionally and conditional on a long list of standard variables, including urban or rural residence (Glaeser and Glendon 1998).

Notice that equal concentration is only a necessary condition for characteristic stories such as these to work. Even if blacks were eight times as likely as whites to be poor, for instance, poverty differentials would explain the robbery arrest disparity only if the non-poor were never arrested for robbery. Thus Lochner and Moretti (2004) find that equalizing black and white educational attainment would eliminate only 23% of the racial incarceration gap (which is smaller than the racial robbery arrest gap).²²

Considering the interaction among several characteristics moves us no closer to an explanation. In general, a story about interaction between two characteristics can explain more than the stronger

²¹Note that in our model, blacks and whites with *identical* non-racial characteristics (as represented by θ) will behave differently in equilibrium, since their racial characteristics alone are sufficient to influence beliefs and hence the actions of those with whom they interact.

²²This is their OLS result. They do not report similar calculations for the more sophisticated regressions that they run, but those regressions lead them to conclude that OLS produces a reasonably accurate measurement of the impact of education on crime.

of two simple characteristics stories only in two special circumstances: either crime depends on the intersection and the characteristics are much more strongly correlated among blacks than among whites; or crime depends on the union and the characteristics are much more strongly correlated among whites than among blacks. Analogous conditions hold for 3-way, and n -way interaction. We have found no evidence that either of these special circumstances holds for any set of characteristics.

6.2 Under-deterrence and Social Osmosis

Economic theories of crime emphasize how the probability and severity of punishment deter potential wrong-doers. Under-deterrence, therefore, is a potential explanation for black crime—perhaps African-Americans commit more crimes because they are less afraid of the consequences. This is the operative mechanism is Sah’s (1994) “social osmosis” theory of crime, for instance—neighborhoods with many criminals in them overwhelm the police; this lowers the probability of apprehension, and so perpetuates and exacerbates disparities. This hypothesis also appears in Anderson (1999). His argument is that lawlessness prevails in black neighborhoods because the police have abandoned them and do not treat black-on-black crime sufficiently seriously.

The greatest problem that an under-deterrence theory of racial disparities encounters is that there is no evidence that African-American criminals face lower probabilities of apprehension or less severe punishments. If such were the case, African-Americans would be more heavily represented among offenders identified by victims than among arrestees or prisoners. That is not the pattern we see.

Racial disparities in judicial processing have been studied extensively, and the consensus is that blacks are not treated more leniently than whites. Ayres and Waldfogel (2003) find that African-Americans are forced to pay discriminatorily high bail. The U. S. Office of Juvenile Justice and Delinquency Prevention (1999, p. 3) concluded from a review of many studies that “there is substantial evidence that minority youth are treated differently from majority youth within the juvenile justice system”—being more likely to be placed in public secure facilities, for instance, rather than private facilities or diversion, even considering the severity of the crime and other factors. Sampson and Lauritsen (1997) review the literature on adult case disposition and sentencing. They conclude (p. 355):

When restricted to index crimes, dozens of individual-level studies have shown that a direct influence of race on pretrial release, plea bargaining, conviction, sentence length,

and death penalty among adults is small to nonexistent once legally relevant variables (e.g., prior record) are controlled.

Nor is it plausible to argue that blacks commit more crimes against blacks because their victims are less likely to call the police. Black robbery victims are slightly more likely to report the crime, but the difference was not statistically significant (NCVS 2002, table 94). If police did not treat black victimization as seriously as white, we would expect to see more white-on-black robbery than black-on-white, when in fact the opposite is the case.

The second problem with an under-deterrence theory of racial disparities is that elasticities of crime with respect to deterrence measures are so small that disparities in apprehension and punishment would have to be very great to explain any substantial portion of the disparity. Most econometric estimates (for instance, Witte 1980) put the elasticity of offenses with respect to the probability of arrest or imprisonment in the range of 0.3 to 0.5. Almost certainly it is less than unity. But only if the elasticity of offenses is greater than unity can weaker deterrence explain more per capita arrests. With this elasticity less than unity, a group with a lower threat of arrests would have fewer arrests, not more.

Econometric estimates of the elasticity of offenses with respect to length of sentences generally find that it is lower than the elasticity with respect to arrest probability (“certainty matters more than severity”) and often find that it is very small. Suppose that this elasticity is 0.3—a very high estimate. Then African-Americans would commit twice as many offenses as whites only if their punishment was roughly a tenth of white expected punishment. And African-Americans would commit eight times as many robberies only if whites were punished a thousand times more severely. Considering the volume of research on racial sentence disparities, it is inconceivable that a discrepancy of this magnitude could have been overlooked.

Thus traditional deterrence theory is of little use in explaining racial disparities, and any more imaginative reconstruction (defining the severity of punishment differently, for instance) has very large obstacles to overcome.

6.3 Culture of Violence

Another explanation is that African-American sub-culture is to blame. According to this view, African-Americans live in a sub-culture distinct from the rest of American society, one in which crime, aggressive behaviors, and illegitimate activities are not strongly condemned. Even if this

argument is not taken as a tautology, there are a number of empirical difficulties. Social surveys do not reveal major differences between blacks and whites on attitudes toward crime (Sampson and Lauritsen, 1997, p. 332). Blacks are decidedly more pious and religiously observant than whites, even holding income and education constant (Iannaccone 1998). Freeman (1996) shows that religious youth are less likely to engage in crime. Blacks are less likely to drink, and considerably less likely to abuse alcohol (SAMHSA, 2002). Alcohol is closely linked to violence (Cook and Moore 1993, 2000; Chaloupka and Saffer 1993; Fagan 1993; Markowitz 2000a, 2000b; Markowitz and Grossman 1999a, 1999b). The only hard evidence for a sub-culture of violence, it seems, is violent crime—the phenomenon the sub-culture story is supposed to be explaining.

A culture of violence should mean a culture in which families fight. Yet in 2002, blacks were slightly *less* likely than whites to be victims of violent crimes committed by family members (1.9 per 1000 population 12 or over for blacks, versus 2.0 for whites). Since family violence is decreasing in income, a regression would probably show that “African-American sub-culture” decreases family violence (NCVS, 2004, table 35).

The sub-culture explanation also fails to explain why African-Americans are more heavily over-represented in certain crimes than in others. Drug trafficking, gambling, prostitution, receiving stolen property, and motor vehicle theft are all less violent (and more profitable financially) than rape and assault, but African-Americans are more heavily over-represented in the former crimes than in the latter.

6.4 Physical Size

Group differences in physical size cannot account for differences in robbery rates, for the simple reason that African-American men are no larger than white men of comparable age. On average, black men between 20 and 39 are slightly lighter than non-Hispanic white men (189.1 pounds for African-Americans vs. 189.7 for non-Hispanic whites), and slightly shorter (70.1 inches vs. 70.2 inches). Both differences are statistically insignificant. The mean body mass index is virtually identical across groups (Ogden et al., 2004, tables 11, 13 and 15). Since body mass index is a nonlinear function of height and weight, it is unlikely that higher moments of the black and white bivariate distributions of height and weight differ greatly.

6.5 Adverse Selection

Loury (2002) develops a model of adverse selection to explain why cab drivers fear black men. Out of fear, cab drivers make black men wait longer, and so robbers end up disproportionately represented among the black men who endure and get a cab. This is because robbers gain more from a cab ride than regular passengers do, and so are willing to wait longer. This is an equilibrium in which cab drivers's stereotype of black men as robbers is confirmed.

While this model accounts for discriminatory treatment, it predicts that within the population of passengers white men rob cabs more often than black men do. Robbing cabs is easier for white men than for black, because they do not have to wait as long, and proportionately more of them do it (although robbers are a smaller fraction of riders). Thus a generalization of Loury's model does not predict that blacks will be disproportionately involved in robbery.

6.6 Social Interaction

Glaeser, Sacerdote, and Scheinkman (GSS) (1996) observe that the spatial variation in crime is greater than traditional economic and demographic variables can explain, and develop a theory of social interaction. No matter what your background, if your neighborhood is full of criminals, you're much more likely to become a criminal, too. Since many African-Americans live in segregated neighborhoods with much crime, a theoretical model where social interaction among criminals led to disproportionate African-American criminality probably could be developed.

Such a model, however, would not be able to explain GSS's empirical results on particular index crimes. If social interaction explained African-American involvement in crime, then social interaction should be most powerful for the index crimes African-Americans commit relatively most—murder and robbery—and least powerful for those they commit relatively least—burglary and assault. Instead, GSS conclude that social interaction is of almost negligible power for murder, and only modest power for robbery. Social interaction is of greatest importance for motor vehicle theft, a crime of moderate African-American disproportion, and theft, a crime of little disproportion.

7 Conclusions

The idea that racial stereotypes can have incentive effects that result in systematic differences across groups in behavior dates back to the seminal work of Arrow (1973) and Phelps (1972). Early applications of this idea focused on labor markets, and addressed racial disparities in wages,

job assignment, and human capital acquisition. In order for the theory of statistical discrimination to be operative, however, it is necessary that the characteristics in question be both unobservable and responsive to economic incentives. As noted by (Akerlof, 1976, p.608), there are “difficulties in applying this model to real-world racial discrimination” in labor markets since characteristics such as education and experience are generally observable at little cost, while traits such as punctuality and initiative, being acquired in early childhood, are relatively unresponsive to wage differentials. This suggests that the theory of statistical discrimination may be most relevant to sporadic, anonymous interactions in which payoff-relevant characteristics are necessarily unobservable, and where potential gains and losses can be significant. The crime of robbery satisfies all of these criteria.

Our theory of racial disparities in the incidence of robbery, resistance, and violence is based on the idea that group inequality can affect incentives in ways that induce otherwise identical individuals to behave differently in equilibrium.²³ Victims entertain the belief that black offenders, being drawn from a population with lower levels of income, are more likely than whites to respond violently to resistance. This lowers their incentives to resist and makes crime more lucrative for non-violent black offenders who benefit from (but do not fit) the stereotype. The result is disproportionate involvement of blacks in robbery. For similar reasons, potential robbers believe that black victims are more likely than whites to resist attempts at robbery. This makes them less attractive targets, and explains the huge gap between black-on-white relative to white-on-black crime. An implication of the disparity in crime rates is that black victims face a group of offenders that is on the whole more violent; this prediction of the model is roughly consistent with the empirical record.

One limitation of our work is that potential victims make only one decision—whether or not to resist a robbery attempt. In practice, potential victims can employ a variety of strategies (Ehrlich, 1981 and Cook, 1986). In particular, they can employ costly precautions to avoid being victims of crime at all. Such avoidance behavior explains in part why the old, the rich, and women are less likely to be robbery victims. Allowing victims to take costly precautions is an obvious extension to our model. If moving to areas with few robbers is cheaper for whites than for blacks, then *ceteris paribus* the resistance rates for whites who do not move should be higher. This could explain one of our empirical anomalies. More importantly, racial asymmetry in robbery can then lead to racial segregation and discrimination in housing markets.

²³The idea group inequality can result in differential outcomes for otherwise identical blacks and whites appears also in Sethi and Somanathan (2004), where it is shown that in stable sorting equilibria blacks experience lower neighborhood quality than whites of comparable income.

Finally, we have assumed throughout that beliefs held by both victims and perpetrators are self-fulfilling in equilibrium. This is the hallmark of the economic approach: behavior is optimal given the beliefs that individuals hold, and beliefs are accurate, given the behavior that they induce. Psychologists have long recognized, however, that “stereotypes based on relatively enduring characteristics of the person (such as race, religion and gender) have enormous potential for error” (Hilton and von Hippel, 1996, p. 241). There are a number of channels through which inaccurate stereotypes can arise and persist. Once activated, stereotypes can influence attentiveness to new information, the interpretation of ambiguous information, the behavior of the holder towards the target of the stereotype, and the standards against which the behavior of the target is judged (Hamilton et al., 1994). To the extent that the holder is more receptive to stereotype-confirming information, and tends to interpret ambiguous information in a manner that is stereotype-consistent, beliefs about group characteristics can persist even if they are inaccurate. Such considerations strengthen rather than undermine the conclusions drawn in this paper. The existence of an inaccurate but persistent stereotype of black male violence, for instance, would result in qualitatively similar but quantitatively greater racial disparities in crime rates relative to the predictions of our analysis. We consider the explicit introduction of such psychological perspectives into models of economic behavior to be a promising direction for future research.

Appendix

Proof of Proposition 1. First we show that $\lambda^* < 1$ in any equilibrium. Suppose, instead, that $\lambda^* = 1$. Then $\mu^* = G(\tilde{\theta}(1)) = 0$ from (4) and hence, from (3) and the fact that $F(\hat{\theta}(0)) = 1$, we have

$$\lambda^* = \min \left\{ \frac{F(\bar{\theta})}{F(\hat{\theta}(0))}, 1 \right\} = F(\bar{\theta}) < 1,$$

contradicting the supposition that $\lambda^* = 1$. Hence $\lambda^* < 1$, and we can rewrite (3) as simply

$$\lambda^* = \frac{F(\bar{\theta})}{F(\hat{\theta}(\mu^*))}.$$

Combining this with (4) we get the following single condition for equilibrium:

$$\varphi(\lambda^*) = F(\bar{\theta}), \quad (11)$$

where $\varphi(\lambda^*) = \lambda^* F(\hat{\theta}(G(\tilde{\theta}(\lambda^*))))$. Note that φ is increasing in λ^* , since $\tilde{\theta}(\cdot)$ and $\hat{\theta}(\cdot)$ are both decreasing and $F(\cdot)$ and $G(\cdot)$ are both increasing. Furthermore, $\varphi(0) = 0$ and $\varphi(1) = 1$. The latter follows from the fact that $G(\tilde{\theta}(1)) = 0$ (facing certain violence, all victims comply) and $F(\hat{\theta}(0)) = 1$ (facing certain compliance, all robbers confront). Hence there is a unique value of $\lambda^* \in (0, 1)$ that satisfies the equilibrium condition (11). This implies a unique equilibrium value of μ^* from (4). ■

Proof of Proposition 2. An upward shift in $z_1(\theta)$ implies a decline in $\bar{\theta}$ and hence in $F(\bar{\theta})$. The function $\tilde{\theta}(\lambda^*)$ is unaffected by the change in z_1 , since it is defined implicitly by

$$x_2(\tilde{\theta}) = \lambda z_2(\tilde{\theta}) + (1 - \lambda) y_2(\tilde{\theta}),$$

and the functions x_2 , y_2 , and z_2 are all unchanged. The function $\hat{\theta}(\mu^*)$ is also unaffected, since it is defined implicitly by

$$(1 - \mu) x_1(\hat{\theta}) = \mu \min \left\{ y_1(\hat{\theta}), z_1(\hat{\theta}) \right\}$$

and $\lambda^* < 1$ implies that $\min \left\{ y_1(\hat{\theta}), z_1(\hat{\theta}) \right\} = y_1(\hat{\theta})$ in equilibrium. Since $\tilde{\theta}$ and $\hat{\theta}$ are both decreasing and F and G are increasing and positive, (6) implies that a decline in $F(\bar{\theta})$ must result in a lower λ^* . From this, (4), and the fact that $\tilde{\theta}$ is a decreasing function, we know that μ^* must rise. The overall crime rate $\gamma^* = F(\hat{\theta}(\mu^*))$ therefore falls, since the decreasing function $\hat{\theta}$ has not shifted while μ^* has risen.

A downward shift in $x_1(\theta)$ has no effect on the $\tilde{\theta}(\lambda)$ function, but the $\hat{\theta}(\mu)$ function shifts down (for any given beliefs about resistance fewer robberies are attempted). This follows from the fact

that $\hat{\theta}(\mu)$ is implicitly defined by $(1 - \mu)x_1(\hat{\theta}) = \mu y_1(\hat{\theta})$, there is no change in $y_1(\cdot)$, and $x_1(\cdot)$ is decreasing and has shifted down. This implies from (6) that λ^* is higher in equilibrium, since $F(\bar{\theta})$ is unaffected by the downward shift in $x_1(\theta)$, $\hat{\theta}(\mu)$ has shifted down, and the left-hand-side of (6) is increasing in λ^* . Higher λ^* implies lower μ^* from (4), the fact that $\tilde{\theta}(\lambda)$ is decreasing, and has not been shifted. The overall crime rate $\gamma^* = F(\hat{\theta}(\mu^*))$ must be lower (otherwise λ^* could not have risen, given that $F(\bar{\theta})$ is the same).

An upward shift in $y_1(\hat{\theta})$ results in a decline in $\hat{\theta}(\mu)$. This follows from the fact that $\hat{\theta}(\mu)$ is implicitly defined by $(1 - \mu)x_1(\hat{\theta}) = \mu y_1(\hat{\theta})$, there is no change in $x_1(\cdot)$, and $y_1(\cdot)$ is increasing and has shifted up. There is no effect on either $\tilde{\theta}(\lambda)$ or $F(\bar{\theta})$. Taken together, this implies from (6) that λ^* is higher in equilibrium, and hence from (4) that μ^* is lower (since $\tilde{\theta}(\lambda)$ has not shifted). The overall crime rate $\gamma^* = F(\hat{\theta}(\mu^*))$ must be lower (otherwise λ^* could not have risen, given that $F(\bar{\theta})$ is the same). ■

Proof of Proposition 3. A uniform deterrence increase leaves the function $\tilde{\theta}(\lambda)$ unchanged, since it depends only on victim payoff functions. A uniform deterrence increase also leaves the value $\bar{\theta}$ unchanged, since it is implicitly defined by the equation $y_1(\theta) = z_1(\theta)$, both sides of which increase by the same amount k . Hence $F(\bar{\theta})$ is unchanged. The function $\hat{\theta}(\mu)$, however, is changed. In particular it shifts down for all μ : the threshold value at which potential robbers are willing to attempt robbery falls. Since $\hat{\theta}(\mu)$ falls and the other functions defining $\varphi(\lambda)$ remain the same, $\varphi(\lambda)$ falls for all λ . (Here $\varphi(\lambda) = \lambda F(\hat{\theta}(G(\tilde{\theta}(\lambda))))$ as in the proof of Proposition 1.) Since $\varphi(\lambda)$ is increasing, it follows from (6) that λ^* increases. Since λ^* increases, $\mu^* = G(\theta(\lambda^*))$ falls. Since $\gamma^* = F(\bar{\theta})/\lambda^*$, by definition, γ^* falls. ■

Proof of Proposition 4. With all payoff functions unchanged, there is no shift in the threshold $\bar{\theta}$ or in the functions $\hat{\theta}(\cdot)$ and $\tilde{\theta}(\cdot)$. The share of violent types in the population as a whole, $F(\bar{\theta})$ must fall. Suppose, by way of contradiction, that the crime rate $\gamma^* = F(\hat{\theta}(\mu^*))$ does not fall. Then from (5), λ^* must be lower, and hence from (4), μ^* must be higher. But since $\hat{\theta}(\mu^*)$ is a decreasing function and $F(\cdot)$ has shifted down, this implies a lower crime rate $\gamma^* = F(\hat{\theta}(\mu^*))$, a contradiction. ■

Proof of Proposition 5. Consider the condition (6) with the new distribution H but the old equilibrium λ^* . We claim that

$$\lambda^* H\left(\hat{\theta}\left(G\left(\tilde{\theta}(\lambda^*)\right)\right)\right) > H(\bar{\theta}). \quad (12)$$

To see why, note that

$$\begin{aligned}\lambda^* H\left(\hat{\theta}\left(G\left(\tilde{\theta}(\lambda^*)\right)\right)\right) &= \lambda^* F\left(\hat{\theta}\left(G\left(\tilde{\theta}(\lambda^*)\right)\right)\right) \left(\frac{H\left(\hat{\theta}\left(G\left(\tilde{\theta}(\lambda^*)\right)\right)\right)}{F\left(\hat{\theta}\left(G\left(\tilde{\theta}(\lambda^*)\right)\right)\right)}\right) \\ &> \lambda^* F\left(\hat{\theta}\left(G\left(\tilde{\theta}(\lambda^*)\right)\right)\right) \left(\frac{H(\bar{\theta})}{F(\bar{\theta})}\right)\end{aligned}$$

since $\hat{\theta} > \bar{\theta}$ from Proposition 1, and $H(\theta)/F(\theta)$ is increasing in θ . But from (6),

$$\lambda^* F\left(\hat{\theta}\left(G\left(\tilde{\theta}(\lambda^*)\right)\right)\right) \left(\frac{H(\bar{\theta})}{F(\bar{\theta})}\right) = F(\bar{\theta}) \left(\frac{H(\bar{\theta})}{F(\bar{\theta})}\right) = H(\bar{\theta}).$$

This establishes the claim (12). The new equilibrium value of λ is defined by $\lambda H(\hat{\theta}(G(\tilde{\theta}(\lambda)))) = H(\bar{\theta})$. Since $\lambda H(\hat{\theta}(G(\tilde{\theta}(\lambda))))$ is an increasing function of λ , (12) implies that the new equilibrium value of λ must be smaller than λ^* . Since the function $\tilde{\theta}(\lambda)$ is unchanged and decreasing, (4) implies that the new equilibrium value of μ is higher. ■

Proof of Proposition 6. The first step is to show that both changes reduce $G(\tilde{\theta}(\lambda))$ for all λ . For the rightward shift in the distribution of victim types, this result is obvious, since the function $\tilde{\theta}(\lambda)$ does not change. Greater expected cost of violence shifts the $\tilde{\theta}(\cdot)$ down, and so reduces $G(\tilde{\theta}(\lambda))$. Since $\hat{\theta}(\mu)$ is a decreasing function, $\varphi(\lambda) = \lambda F(\hat{\theta}(G(\tilde{\theta}(\lambda))))$ rises for all λ . Hence $\varphi(\lambda^*) > F(\bar{\theta})$. Since $\varphi(\lambda)$ is an increasing function, λ^* must fall. From (5) and $F(\bar{\theta})$ unchanged, $\gamma^* \equiv F(\hat{\theta}(\mu^*))$ must rise. Since $\hat{\theta}$ is a decreasing function and F is increasing, μ^* must fall. ■

Proof of Proposition 7. Suppose $F_b(\theta) > F_w(\theta)$ for all $\theta \in \Theta$. Then, in particular, $F_b(\bar{\theta}) > F_w(\bar{\theta})$. Now suppose (by way of contradiction) that $\gamma_{bj}^* \leq \gamma_{wj}^*$ for some $j \in \{b, w\}$. Recall that $\gamma_{ij}^* = F_i(\hat{\theta}(\mu_{ij}^*))$ by definition, so from (7), we obtain $\lambda_{bj} > \lambda_{wj}$. Since $\tilde{\theta}(\cdot)$ is decreasing and $G_j(\cdot)$ is increasing, this implies $\mu_{bj} < \mu_{wj}$ from (8). But since $\hat{\theta}(\cdot)$ is decreasing, F_w is increasing, and $F_b(\theta) > F_w(\theta)$ for all $\theta \in \Theta$, we obtain:

$$\gamma_{wj}^* \equiv F_w\left(\hat{\theta}(\mu_{wj}^*)\right) < F_w\left(\hat{\theta}(\mu_{bj}^*)\right) < F_b\left(\hat{\theta}(\mu_{bj}^*)\right) \equiv \gamma_{bj}^*,$$

which contradicts the hypothesis that $\gamma_{bj}^* \leq \gamma_{wj}^*$. Hence $\gamma_{bj}^* > \gamma_{wj}^*$ for all $j \in \{b, w\}$.

Now suppose that $F_b(\theta)$ is strongly tougher than $F_w(\theta)$, so $F_w(\theta)/F_b(\theta)$ is nondecreasing. Consider any $j \in \{b, w\}$. We claim that

$$\lambda_{bj}^* F_w\left(\hat{\theta}\left(G_j\left(\tilde{\theta}(\lambda_{bj}^*)\right)\right)\right) > F_w(\bar{\theta}). \quad (13)$$

To see why, note that

$$\begin{aligned}\lambda_{bj}^* F_w \left(\hat{\theta} \left(G_j \left(\tilde{\theta} \left(\lambda_{bj}^* \right) \right) \right) \right) &= \lambda_{bj}^* F_b \left(\hat{\theta} \left(G_j \left(\tilde{\theta} \left(\lambda_{bj}^* \right) \right) \right) \right) \left(\frac{F_w \left(\hat{\theta} \left(G_j \left(\tilde{\theta} \left(\lambda_{bj}^* \right) \right) \right) \right)}{F_b \left(\hat{\theta} \left(G_j \left(\tilde{\theta} \left(\lambda_{bj}^* \right) \right) \right) \right)} \right) \\ &> \lambda_{bj}^* F_b \left(\hat{\theta} \left(G_j \left(\tilde{\theta} \left(\lambda_{bj}^* \right) \right) \right) \right) \left(\frac{F_w(\bar{\theta})}{F_b(\bar{\theta})} \right)\end{aligned}$$

since $\hat{\theta} > \bar{\theta}$ from Proposition 1, and F_w/F_b is increasing in θ . But from (7–8),

$$\lambda_{bj}^* F_b \left(\hat{\theta} \left(G_j \left(\tilde{\theta} \left(\lambda_{bj}^* \right) \right) \right) \right) \left(\frac{F_w(\bar{\theta})}{F_b(\bar{\theta})} \right) = F_b(\bar{\theta}) \left(\frac{F_w(\bar{\theta})}{F_b(\bar{\theta})} \right) = F_w(\bar{\theta}),$$

which proves that (13) holds. Note that from (7–8), we have

$$\lambda_{wj}^* F_w \left(\hat{\theta} \left(G_j \left(\tilde{\theta} \left(\lambda_{wj}^* \right) \right) \right) \right) = F_w(\bar{\theta})$$

Since $\lambda F_w(\hat{\theta}(G_j(\tilde{\theta}(\lambda))))$ is an increasing function of λ , (13) implies that $\lambda_{wj}^* < \lambda_{bj}^*$. Since the function $\tilde{\theta}(\lambda)$ is unchanged and decreasing, and G_j is increasing, (8) then implies that $\mu_{wj}^* > \mu_{bj}^*$. ■

Proof of Proposition 8. Suppose $G_b(\theta) > G_w(\theta)$ for all $\theta \in \Theta$ and suppose (by way of contradiction) that $\gamma_{iw}^* \leq \gamma_{ib}^*$ for some $i \in \{b, w\}$. Then, by definition of γ_{ij} , we have $F_i(\hat{\theta}(\mu_{iw}^*)) \leq F_i(\hat{\theta}(\mu_{ib}^*))$. From (7), therefore, $\lambda_{ib} \leq \lambda_{iw}$. Using this, together with (8) and the facts that $\tilde{\theta}(\cdot)$ is decreasing, $G_w(\cdot)$ is increasing, and $G_b(\theta) > G_w(\theta)$ for all $\theta \in \Theta$, we get

$$\mu_{iw}^* = G_w(\tilde{\theta}(\lambda_{iw}^*)) \leq G_w(\tilde{\theta}(\lambda_{ib}^*)) < G_b(\tilde{\theta}(\lambda_{ib}^*)) = \mu_{ib}^*$$

and hence $\mu_{iw}^* < \mu_{ib}^*$. Using this, the fact that $\hat{\theta}(\cdot)$ is decreasing and F_i is increasing for each $i \in \{b, w\}$, we get

$$\gamma_{ib}^* \equiv F_i(\hat{\theta}(\mu_{ib}^*)) < F_i(\hat{\theta}(\mu_{iw}^*)) \equiv \gamma_{iw}^*,$$

contradicting the hypothesis that $\gamma_{iw}^* \leq \gamma_{ib}^*$. Hence $\gamma_{ib}^* < \gamma_{iw}^*$ for all $i \in \{b, w\}$.

To obtain the results for λ and μ , recall that for any $i, j \in \{b, w\}$, $\lambda F_i(\hat{\theta}(G_j(\tilde{\theta}(\lambda))))$ is increasing in λ . Since $\hat{\theta}(\cdot)$ is decreasing, and $G_b(\theta) > G_w(\theta)$ for all θ , we therefore have

$$\lambda_{ib}^* F_i \left(\hat{\theta} \left(G_w \left(\tilde{\theta} \left(\lambda_{ib}^* \right) \right) \right) \right) > \lambda_{ib}^* F_i \left(\hat{\theta} \left(G_b \left(\tilde{\theta} \left(\lambda_{ib}^* \right) \right) \right) \right) = F_i(\bar{\theta}),$$

where the last equality follows from the equilibrium conditions (7–8). The same conditions imply

$$\lambda_{iw}^* F_i \left(\hat{\theta} \left(G_w \left(\tilde{\theta} \left(\lambda_{iw}^* \right) \right) \right) \right) = F_i(\bar{\theta}),$$

and so we have.

$$\lambda_{ib}^* F_i \left(\hat{\theta} \left(G_w \left(\tilde{\theta} \left(\lambda_{ib}^* \right) \right) \right) \right) > \lambda_{iw}^* F_i \left(\hat{\theta} \left(G_w \left(\tilde{\theta} \left(\lambda_{iw}^* \right) \right) \right) \right)$$

Since $\lambda F_i(\hat{\theta}(G_w(\tilde{\theta}(\lambda))))$ is increasing in λ , it must be the case that $\lambda_{ib}^* > \lambda_{iw}^*$. From (7), this implies $F_i(\hat{\theta}(\mu_{ib}^*)) < F_i(\hat{\theta}(\mu_{iw}^*))$ and hence, since $\hat{\theta}(\cdot)$ is decreasing and $F_i(\cdot)$ increasing, we have $\mu_{iw}^* < \mu_{ib}^*$ as claimed. ■

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