Social Osmosis and Patterns of Crime

Raaj K. Sah

University of Chicago

Crime and the fear of crime have a deep negative impact on personal and societal well-being. Several observed patterns regarding criminal behavior, however, remain inadequately understood. In this analysis, individuals' perceptions (concerning their probabilities of punishment) and choices are determined endogenously, while incorporating the information available to them and how this information is generated within the economy. The resulting dynamic relationships are then studied to examine how criminality might evolve over time, why crime participation rates might differ among societal groups even when they face similar economic fundamentals, and how the features of the economy might affect these rates.

Crime and the fear of crime have a deep negative impact on the well-being of individuals and societies. In the United States, recent opinion surveys show that most people view crime to be their single most important problem, more important than any economic hardship. However, several observed patterns concerning criminal behavior are not adequately understood at present. For example, crime participation rates in different societal groups are often correlated with such background variables as location (city centers vs. suburbs vs. rural communities), age structure, and ethnicity (e.g., blacks vs. whites in the United States), even after a large number of economic

I thank Gary Becker, Michael Block, Nancy Gallini, Henry Hansmann, James Heckman, Edward Lazear, Kevin Murphy, Sherwin Rosen, Alan Schwartz, Michael Trebilcock, and an anonymous referee for their many valuable suggestions, and Alejandro Ascencios, James Robinson, and Naomi Zellner for their assistance.

[*Journal of Political Economy*, 1991, vol. 99, no. 6]
© 1991 by The University of Chicago. All rights reserved. 0022-3808/91/9906-0008$01.50

and deterrence variables are controlled for.[1] Regardless of one's normative views, a positive understanding of such patterns is essential.

To see one of the points of departure of this paper, consider Becker's (1968) seminal study, which has inspired a valuable literature.[2] In this study, a key ingredient in an individual's choice of whether or not to be a criminal is his or her perceived probability of punishment. I use the symbol p to refer to this probability, representing the individual's *perception,* and r to refer to his actual probability of punishment, representing the corresponding *reality.* This literature assumes that p is an exogenous parameter to the individual, and it typically makes the much stronger assumptions that all individuals have identical and exogenously given perceptions and that these are the same as the reality.

Now, consider some of the survey-based evidence concerning individuals' self-reported perceptions. (*a*) A large variance in p's within a societal group is observed, regardless of its characteristics (e.g., income, education, gender, and ethnicity), even for a narrowly defined crime (e.g., theft of $50). Many studies, including those cited below, report this finding. (*b*) There are significant differences in the distribution of p's across different groups (see Carter and Hill [1978], Richards and Tittle [1982], Piliavin et al. [1986], and references therein). (*c*) An individual's p changes over time (see Piliavin et al. [1986] and other longitudinal studies they cite). However, the mass media do not significantly influence this change, whereas past experiences of the individual and of his acquaintances (e.g., friends, peers, and relatives) do. The preceding two categories of past experiences do not appear to have significantly different influences (see Parker and Grasmick 1979).

Next, consider experts who conduct research on crime rather than just ordinary individuals. The experts typically disagree on the values of r in the past, let alone its current value. This well-known problem arises because crime statistics are highly unreliable, given that an accurate reporting of crimes is missing and is hard to induce. This has been routinely shown by studies of self-reported criminality. For example, in a sample of 2,510 adult American males, 44 percent admitted to shoplifting, whereas only a minuscule fraction of the corresponding population is ever punished for this crime (O'Donnell et al. 1976, pp. 81–82). Since the estimation of r is a costly inference

[1] See Bureau of Justice Statistics (1983, 1988) for exhibits of U.S. data. See Pyle (1983, chap. 3) for a review of more than 20 empirical studies and for other references.

[2] See Ehrlich (1973), Becker and Landes (1974), Block and Heineke (1975), Heineke (1978), Andreano and Siegfried (1980), Pyle (1983, chaps. 2, 5), Schmidt and Witte (1984), Klevorick (1985), and references therein for models, applications, and reviews.

problem for an expert researcher, it is reasonable to posit that an ordinary individual faces a much more difficult and costly inference problem.

Thus there is a clear need to examine the determinants of the p's and the impact that an endogenous determination of p's might have on the aggregate criminal behavior. This is especially true for analyses based on economic reasoning because an individual with a lower p will have a higher propensity for crime. This link, apart from being well grounded in theory, has been established in many studies based on individual-level data, including an exhaustive study by Montmarquette and Nerlove (1985).

This paper's perspective on perceptions is as follows. An individual's p is an endogenous outcome of the nature of the information available to him. This information is, in turn, generated within the economy. However, there is no source in the economy from which the individual can in practice get the accurate information. He may receive raw data from several sources, but each source has its own costs, inaccuracies, and randomness. For example, casual contact or hearsay yields unreliable data. The individual's own past experiences and those of his acquaintances are more reliable, but, for reasons noted later, they provide limited information. The mass media are an inexpensive source of data that is common to many individuals, but it is largely irrelevant for the issue at hand. Intensive media coverage of a small subset of reported crimes, chosen primarily for their sensational impact, contains virtually no useful information on r.

I therefore emphasize the following key features of the nature of the information available to an individual: (i) The relevant information is limited. (ii) Its primary source to an individual is his "vicinity" (i.e., himself and his acquaintances). (iii) To an extent, an individual's current information reflects the values of r in some periods of the past. For example, the past punishment experiences of criminals in one's vicinity depend stochastically on the values of r in the corresponding periods. (iv) Such information concerning past values of r is an imperfect predictor of the current value of the individual's r because the information is local, limited, and stochastic and also because the values of r may be changing for a variety of reasons.

An individual's perceptions, thus obtained, determine, in combination with his opportunities, his current choice of whether or not to be a criminal. These choices, aggregated across individuals, yield the "crime participation rate," that is, the fraction of individuals in the population, or a societal group, who have chosen to be criminals. The current crime participation rates in different societal groups affect the current actual probabilities of punishment, the r's. The reason is that for any given public expenditure on the "criminal apprehension

system,"[3] a higher crime participation rate leads to fewer resources being spent on apprehending each criminal, which lowers the r's. The current values of the r's and the current crime participation rates, in turn, influence future perceptions, choices, and crime participation rates. My qualitative analysis of the resulting dynamic relationships focuses on examining how crime participation rates might evolve over time, how the parameters of the economy might affect these rates, why crime participation rates might differ across societal groups, how criminality might spill over across groups, and how a change in the degree of intergroup segregation might affect different groups' crime participation rates.

To keep the paper within its present length, I provide only an outline of the mathematical derivations and also adopt several boundaries. For instance, this paper's positive analysis takes the penalty schedule and the criminal apprehension system as given and then examines how crime patterns might change if these were altered. This can be extended, by including a theory of state and an endogenous government budget constraint, to endogenize the government's response. The present analysis is an essential step in studying this topic.

Section I examines an individual's perception, choice, and propensity for crime. Section II examines the economywide crime participation rate. Section III presents a useful simplification in which individuals' perceptions are described by Bayesian inference. Section IV examines crime participation rates in different societal groups. Section V discusses some extensions. Section VI presents some brief remarks.

I. An Individual's Perception and Choice

This section first describes an individual's perception and choice. It then derives some properties of his propensity for crime. Several simplifying assumptions employed here are later relaxed.

Consider an individual who begins his active life in period t. In each period, he faces the choice of whether or not to be a criminal. His characteristics, to be discussed later, are denoted by the vector $\mathbf{h}$. Let $p(t, T, \mathbf{h})$ denote his estimate, at the beginning of period T, of the probability of punishment if he chooses to be a criminal in that period. He is active for L periods ($L \geq 2$).[4]

[3] In this paper, this shorthand phrase describes various public activities to apprehend and punish criminals.

[4] I do not consider the unrealistic case in which L is infinite because it will later lead to the purely technical inconvenience of having to deal with difference equations with infinite lags.

The Payoffs

The individual's expected net utility (including all benefits, costs, and uncertainties concerning the payoffs) in a period is u_0 if he chooses not to be a criminal. Otherwise, it is u_2 if he is punished or u_1 if he is not punished ($u_1 > u_2$). Thus his optimal choice is to be a criminal in period T if and only if

$$u \geq p(t, T, \mathbf{h}), \tag{1}$$

where $u \equiv (u_1 - u_0)/(u_1 - u_2)$. In (1), the individual chooses to be a criminal if he is indifferent between the choices; the alternative assumption does not alter the analysis. His choice is not strategic because the economy has a large population, and any one person's choice has a negligible impact on the criminal apprehension system.

Let us interpret u as the "relative payoff from crime" because it is smaller if the payoff from noncrime activities is larger or if the penalty is more severe. Assume for now that u is an exogenous parameter that is the same for all individuals. Also assume that $u_1 > u_0 > u_2$; that is, an individual is ex post worse off or better off being a criminal depending on whether or not he is punished. This implies that $1 > u > 0$.[5]

The Economywide Crime Participation Rate

Let $c(t, T, \mathbf{h}, u)$ denote the probability that the individual described above will choose to be a criminal in period T. I shall refer to c as his "propensity for crime" in period T. From (1),

$$c(t, T, \mathbf{h}, u) \equiv \text{prob}\{u \geq p(t, T, \mathbf{h})\}. \tag{2}$$

In each period, a new cohort enters the economy while an old cohort leaves. Assume at present that all individuals have similar characteristics, represented by the vector $\mathbf{h}$. Thus (2) also represents the fraction of individuals in the relevant cohort who will choose to be criminals in period T. When (2) is averaged across cohorts, the crime participation rate in period T is

$$C(T) \equiv \frac{1}{L} \sum_{t=T-L+1}^{T} c(t, T, \mathbf{h}, u). \tag{3}$$

[5] In a more general formulation, discussed later, individuals may have different u's. In this formulation, one does not need to make the last assumption for all individuals. In particular, this formulation can accommodate those individuals who, regardless of their perceptions, *will not* choose to be criminals (i.e., $u < 0$) and those who, regardless of their perceptions, *will* choose to be criminals (i.e., $u > 1$).

Here, each cohort has the same population; population changes can be easily included.

The Information Available to an Individual

Let us begin with a simple specification that captures the key features of this information that were noted in the Introduction. This specification can be easily generalized.

In each period, an individual collects observations on n persons, where n is a positive but small number. He also observes how many of these n persons have chosen to be criminals and how many of them, in turn, have been punished. His current p, then, is influenced by his observations accumulated to date. Let the random variable $x(\tau)$ denote the number of criminals the individual has observed, among n persons, in period τ. Let the random variable $y(\tau)$ denote the number of criminals, among these $x(\tau)$, who were punished. Define vectors $\mathbf{x}(t, T) \equiv (x(t), \ldots, x(T-1))$ and $\mathbf{y}(t, T) \equiv (y(t), \ldots, y(T-1))$. Thus the individual's perception, $p(t, T, \mathbf{h})$, can be described by a reduced-form function, P, of $\mathbf{x}$ and $\mathbf{y}$:

$$p(t, T, \mathbf{h}) = P(\mathbf{x}(t, T), \mathbf{y}(t, T), \mathbf{h}). \tag{4}$$

As we shall see, Bayesian inference is a special case of this formulation. From (2) and (4), then, the individual's propensity for crime in period T is

$$c(t, T, \mathbf{h}, u) \equiv \text{prob}\{u \geq P(\mathbf{x}(t, T), \mathbf{y}(t, T), \mathbf{h})\}. \tag{5}$$

This specification can be easily reinterpreted or expanded. For example, in (4), a criminal's punishment plays the same informational role no matter who that criminal is. Instead, the individual may give a different weight to his own experience than to observations concerning others. Likewise, he may give a different weight to observations that are more vivid (e.g., seeing his father in jail) or more recent (see Nisbett and Ross [1980] on the role of vividness). Another simplification implicit here is that a punished criminal returns to the population in the next period. This can be changed by including incarceration. The mass media can be viewed as a source that provides a category of data that, though common to many individuals, contains virtually no information for inferring r. Hearsay and other similar observations can be modeled as unreliable data. In fact, no observation is error-free, except one's own past experiences, because even the experiences of one's acquaintances partly reflect their characteristics. As far as an individual's inference is concerned, the net effect of a given number of observations containing errors is nearly the same as that of fewer error-free observations, as depicted in (4).

Furthermore, n, the number of persons from whom the individual collects observations in each period, may be random or partly chosen by the individual, given relevant benefits and costs. Also, the nature of the observations may be partly state dependent; for example, an incarcerated criminal may be influenced by his closer, but not always accurate, access to other criminals' experiences. These and similar modifications do not alter the principal qualitative properties of individual behavior, such as (6), to be described below. Moreover, our primary concern here is with the key economic features of the nature of the information available to an individual, and not with the details of the specification per se.

A Property of Perceptions

A mild form of rationality in an individual's perception is that his current p is larger if a larger proportion of those criminals whom he has observed in a past period have been punished. The latter happens in period τ if $x(\tau)$ is smaller for a given $y(\tau)$ or if $y(\tau)$ is larger for a given $x(\tau)$. Thus

$$\frac{\partial P}{\partial x(\tau)} < 0, \quad \frac{\partial P}{\partial y(\tau)} > 0 \quad \text{for } T - 1 \geq \tau \geq t. \tag{6}$$

As we shall see, this property is automatically satisfied if the perception is described by Bayesian inference.

Further, an individual is more likely to observe a larger number of criminals in any given period if the crime participation rate is higher in that period. The reason is that a higher crime participation rate induces a first-order stochastic improvement in the probabilities of observing different numbers of criminals. That is,

$$\frac{\partial}{\partial C(\tau)} \operatorname{prob}\{x(\tau) \geq s\} > 0 \quad \text{for any } s \text{ such that } n \geq s \geq 1. \tag{7}$$

This expression and (9) below are derived in the Appendix.

The Actual Probability of Punishment

Assume at present that this probability, denoted by $r(T)$ for period T, is the same for all individuals in the economy. This aspect can be easily modified by defining cohort-, group-, neighborhood-, or individual-specific probabilities. The probability $r(T)$ is an output of the criminal apprehension system; the resources spent on the system in period T, denoted by $E(T)$, are an input, and the crime participation rate in that period is a "negative input" to this system. Thus

$$r(T) \equiv R(C(T), E(T)), \tag{8}$$

where $R_C(T) \equiv \partial R/\partial C(T) < 0$ and $R_E(T) \equiv \partial R/\partial E(T) > 0$. That is, $r(T)$ is smaller if more crimes have occurred in period T or if fewer resources have been spent on the criminal apprehension system. In either case, fewer resources are available for apprehending each criminal. It is assumed throughout that $1 > r(T) > 0$.

The effect of r on an individual's observations is easily ascertained. If $r(T)$ is larger, then the individual is more likely to find a larger number of criminals punished within the subset he has observed in period T. The reason is that a larger $r(T)$ induces a first-order stochastic improvement in the probabilities of finding different numbers of criminals being punished. That is,

$$\frac{\partial}{\partial r(\tau)} \operatorname{prob}\{y(\tau) \geq w\} > 0 \quad \text{for any } w \text{ such that } x(\tau) \geq w \geq 1. \tag{9}$$

It is apparent from (4) that an older individual will have more information on the past values of r. If the value of r does not change much over time, then his current p can be close to the current value of r. By the same token, in accord with the evidence noted in the Introduction, there can be considerable variance in the p's of particular cohorts. Also, the p's may differ considerably from r.

Some Properties of an Individual's Propensity for Crime

Expression (7) shows how the crime participation rate $C(\tau)$ influences the probabilities of different values of $x(\tau)$. Expression (9) shows how $r(\tau)$ influences the probabilities of different values of $y(\tau)$. From (5), therefore, an individual's propensity for crime can be expressed as a reduced-form function, g, of the crime participation rates and the values of r in the relevant past periods:

$$c(t, T, \mathbf{h}, u) \equiv g(C(t), \ldots, C(T-1), r(t), \ldots, r(T-1), \mathbf{h}, u), \tag{10}$$

where the C's and r's on the right-hand side influence the individual's current perception.

Let us now evaluate how the individual's current propensity for crime is affected by past crime participation rates, past values of E, and the payoff from crime. The following properties of (10) are derived in the Appendix:

$$\frac{\partial g}{\partial r(\tau)} < 0, \quad \frac{\partial g}{\partial u} > 0. \tag{11}$$

That is, an individual's propensity for crime is higher if r was lower during a past period of his active life or if the relative payoff from crime is higher. The latter effect is straightforward. The former effect arises because a lower r makes it more likely that a smaller num-

ber of criminals are punished within any subset of criminals. In turn, the individual will be more likely to lower his current and future p's. Consequently, his propensity for crime will increase.

To examine the effect of E's, use (8), (10), and (11) to obtain

$$\frac{dg}{dE(\tau)} = R_E(\tau)\frac{\partial g}{\partial r(\tau)} < 0. \tag{12}$$

That is, an individual has a higher current propensity for crime if fewer resources were spent on the criminal apprehension system during a past period of his active life. The underlying intuition is simple. Fewer resources dilute the resources spent on apprehending each criminal. The resulting decline in r leads to an increase in the individual's propensity for crime, for the reasons described in the previous paragraph.

To examine the effect of past crime participation rates, use (8) and (10) to obtain

$$\frac{dg}{dC(\tau)} = R_C(\tau)\frac{\partial g}{\partial r(\tau)} + \frac{\partial g}{\partial C(\tau)}. \tag{13}$$

The two terms on the right-hand side describe two different effects that a higher past crime participation rate has on an individual's propensity for crime. The first term keeps unchanged the number of criminals that he has observed and calculates the effect that a higher crime participation rate has through its impact on $r(\tau)$. This term is positive from (8) and (11). Since a higher crime participation rate in a period dilutes the resources spent on apprehending each criminal, it decreases r in that period. Hence, for reasons described earlier, an individual's propensity for crime increases. The second term on the right-hand side of (13), namely,

$$\frac{\partial g}{\partial C(\tau)}, \tag{14}$$

keeps $r(\tau)$ unchanged and calculates the impact that a higher crime participation rate, $C(\tau)$, has through its impact on how many criminals the individual is likely to observe. It is shown in the Appendix that a sufficient but not necessary condition for (14) to tend to a nonnegative number is that $r(\tau)$ tend to zero. It is possible to establish weaker conditions that are sufficient for (14) to be nonnegative.

Now, in practice, the magnitude of r is very small. For instance, in the United States, it is estimated that fewer than one-third of crimes are reported. Fewer than one-fifth of the reported crimes lead to an arrest. Further, even for serious crimes, fewer than half of the arrests lead to incarceration. Such estimates obviously differ for different categories of crime (see, e.g., Bureau of Justice Statistics 1983,

pp. 24–25, 45, 52–53) and are not robust, as noted in the Introduction. They nevertheless indicate that, for most crimes, r has a very small order of magnitude.

Next, recall that the first term on the right-hand side of (13) is unambiguously positive. Thus it is reasonable to posit that (13) is positive in practice. That is,

$$\frac{dg}{dC(\tau)} > 0. \tag{15}$$

The conclusions obtained in this subsection are summarized in the following proposition.

PROPOSITION 1. An individual's current propensity for crime is higher if during a past period of his life the crime participation rate was higher or if fewer resources were spent on the criminal apprehension system. The propensity is also higher if the current relative payoff from crime is larger.

II. The Economywide Crime Participation Rate

This section derives the current economywide crime participation rate as a function of some past and present variables. It then identifies some of the properties of the crime participation rate, including how it might change because of a change in the economy's parameters.

Aggregation of (10) across cohorts, according to (3), allows us to define a reduced-form function, f, described below, for the current economywide crime participation rate:

$$\begin{aligned} C(T) &\equiv \frac{1}{L} \sum_{t=T-L+1}^{T} c(t, T, \mathbf{h}, u) \\ &= f(C(T-1), \ldots, C(T-L+1), E(T-1), \ldots, \\ &\quad E(T-L+1), \mathbf{h}, u, \text{other parameters}). \end{aligned} \tag{16}$$

This is a discrete dynamic system of order $L - 1$. Using (10), (11), (12), (15), and (16), we obtain

$$\frac{\partial C(T)}{\partial C(T-\tau)} > 0 \quad \text{for } L - 1 \geq \tau \geq 1, \tag{17}$$

$$\frac{\partial C(T)}{\partial E(T-\tau)} < 0 \quad \text{for } L - 1 \geq \tau \geq 1, \tag{18}$$

and

$$\frac{\partial C(T)}{\partial u} > 0. \tag{19}$$

Expressions (17) and (18) show how the current crime participation rate is affected by the crime participation rates and the resources spent on the criminal apprehension system during the past $L - 1$ periods, which is how long the oldest cohort has been active. As in any dynamic system, the variables from a more distant past period can have indirect effects on the current outcome. For example, suppose that the crime participation rate was higher in a past period. Then, through (16), the rates in the immediate subsequent periods will be higher, and this chain of influence will be felt on future rates, even though the magnitude of the influence may keep declining. Thus, using (17), (18), and (19), we obtain the following economywide analogue of proposition 1.

PROPOSITION 2. Past crime breeds future crime. That is, the current crime participation rate is higher if the crime participation rate was higher in a past period. The current crime participation rate is also higher if fewer resources were spent on the criminal apprehension system in a past period or if the current relative payoff from crime is larger.

Stable Steady-State Crime Participation Rates

To examine some issues, such as the impact of a change in the economy's parameters on the crime participation rate, it is useful to look at the steady states of dynamic system (16). A steady state here is a hypothetical situation in which the period-to-period changes in the crime participation rates are negligible. As in many other dynamic economic contexts, the steady states provide a convenient apparatus to study the underlying economic forces. It is not being suggested that a real economy actually arrives at a steady state, because shocks may routinely impinge on it. Also, a steady state here does not depict any kind of equilibrium because there are no agents in the economy who can or wish to eliminate period-to-period changes. I focus on the steady states that are locally stable, that is, on "sinks" (see Hirsch and Smale [1974, p. 280] for a definition). If the crime participation rate is close to such a steady state, then subsequent to small shocks, future rates will not diverge away rapidly. Also, I focus on interior steady states, that is, on those in which the crime participation rates are larger than zero but smaller than one.[6]

[6] A clarification is needed here. Proposition 2 shows that past crime breeds future crime. One might thus conclude that the economy must eventually gravitate toward complete criminality because any shock that raises the current crime participation rate will induce higher and higher future rates, thereby ruling out interior steady states. To see why this is not the case, suppose that the economy is currently at an interior steady state with rate C and that a one-time exogenous shock has raised this rate to C

Some Properties of the Crime Participation Rate

Let C denote a stable interior steady-state crime participation rate. Let E denote the unchanging level of resources spent per period on the criminal apprehension system. In (16), substitute C for $C(\tau)$'s and E for $E(\tau)$'s. Let F denote the resulting value of f. Note, for later use, that F represents the current crime participation rate, as determined by past variables. At a steady state, F must equal C. Thus steady-state crime participation rates are those values of C that satisfy the equation

$$C = F(C, E, \mathbf{h}, u, \text{other parameters}). \tag{20}$$

In general, the function F is highly nonlinear in C, as we shall see in the next section. Equation (20) will thus admit multiple values of C as solutions. A consequence of this is the following proposition.

PROPOSITION 3. Two societies with identical parameters can have different steady-state crime participation rates.

This result follows from the earlier dynamic analysis. If two economies have identical parameters in the current and future periods but one of them has had higher crime participation rates in some recent past periods, then this economy can have higher future crime participation rates.

For comparative statics of a steady state, let θ denote a parameter, and let (20) be stated as $C = F(C, \theta)$. Perturbation of this equation with respect to a sustained change in θ yields $dC/d\theta = F_\theta/(1 - F_C)$. (Here and elsewhere in the paper, a letter subscript represents the variable with respect to which a partial derivative is being taken. Also, these comparative statics are in the neighborhood of a stable steady state.) Note that (17) implies that $F_C(C) > 0$. Also, C satisfies $1 > F_C(C)$, which is a necessary condition for C to be stable (see Sah 1989*b*). We thus obtain

$$\operatorname{sgn}\left(\frac{dC}{d\theta}\right) = \operatorname{sgn}(F_\theta), \quad \left|\frac{dC}{d\theta}\right| > |F_\theta|. \tag{21}$$

To interpret (21), recall that F is the current crime participation rate as determined by past variables. Thus F_θ can be viewed as the "first-round" impact of a change in θ on the crime participation rate. Future crime participation rates are altered not only by the changed value

---

$+ \Delta C$. Now the part of the population that has become criminal because of the shock will exit the economy at a future date. Consider a period after this date. From proposition 2, the crime participation rate in this period will be higher than C. However, it can be smaller than $C + \Delta C$. In such cases, the economy will gravitate toward the original crime participation rate C. Thus stable interior steady states are possible. Moreover, one can identify mild conditions that guarantee one or more stable interior steady states (see Sah 1990, p. 27).

of θ but also by a sequence of indirect effects. The difference between the post- and prechange steady-state crime participation rates is described by $dC/d\theta$. Thus expression (21) yields the following proposition.

PROPOSITION 4. The first-round impact of a change in a parameter of the economy on the crime participation rate is preserved in sign but amplified in magnitude as a new steady-state crime participation rate is approached.

This result holds no matter which parameter changes. As an example, suppose that there is a sustained increase in the relative payoff from crime, u. Then from (16), (19), and (20), $F_u > 0$. That is, the first-round impact is an increase in the crime participation rate because the increased attractiveness of crime will induce some individuals to alter their choice. This, in turn, will make it more likely that individuals in the future will have lower p's. This will increase their propensity for crime. The indirect effects thus reinforce the first-round impact.

III. Bayesian Inference

In this section, individuals' perceptions are described by Bayesian inference. This is consistent with the more general formulation employed earlier. The analysis of a steady state presented here is useful later as well, when a multigroup economy is studied.

Consider the perception, in period T, of an individual who became active in period t. Since he has been active for $l \equiv T - t$ periods, he has collected observations on ln persons. Among these ln persons, let $X(t, T) \equiv \Sigma_{\tau=t}^{T-1} x(\tau)$ denote the number of criminals. Among these, let $Y(t, T) \equiv \Sigma_{\tau=t}^{T-1} y(\tau)$ denote the number of those who are punished. Suppose that the individual assumes that, within the time periods of his concern, r is approximated by an unknown fixed number. Suppose that his initial beliefs (i.e., beliefs with which he begins his active life) are represented by a nondegenerate probability density.[7] Then since Y is a sufficient statistic given any X, Bayesian inference implies that the individual's estimate, $p(t, T, \mathbf{h})$, is influenced by $X(t, T)$ and $Y(t, T)$ but not by the individual elements of the vectors $\mathbf{x}(t, T)$ and $\mathbf{y}(t, T)$. Consequently, expression (4) simplifies to

$$p(t, T, \mathbf{h}) = P(X(t, T), Y(t, T), \mathbf{h}). \tag{22}$$

With standard Bayesian techniques, it can be established that

$$P_X < 0, \quad P_Y > 0. \tag{23}$$

[7] This analysis accommodates all types of initial beliefs. The parameters representing these beliefs are a part of the vector of characteristics, $\mathbf{h}$.

That is, an individual has a lower p if a smaller overall proportion of criminals, among those he has observed, have been punished. Thus condition (6) is automatically satisfied by (22).

For an intuitive description of the individual choice, define a function Z through the equality

$$u = P(X, Z(X, \mathbf{h}, u), \mathbf{h}). \tag{24}$$

Define $z(X, \mathbf{h}, u)$ as the largest integer not larger than $Z(X, \mathbf{h}, u)$. Then from (1), (22), (23), and (24), it follows that an individual will choose to be a criminal if and only if

$$Y \leq z(X, \mathbf{h}, u). \tag{25}$$

That is, he will be a criminal if and only if he has found no more than z criminals punished among the X criminals whom he has observed. A natural interpretation of z is as a "reservation level." From (23) and (24),

$$z(X + 1, \mathbf{h}, u) \geq z(X, \mathbf{h}, u), \quad z(X, \mathbf{h}, u') \geq z(X, \mathbf{h}, u) \quad \text{for } u' > u. \tag{26}$$

That is, if an individual has observed a larger number of criminals or if the relative payoff from crime is larger, then his reservation level is not smaller.

Next, let $b(j, X, r) \equiv \binom{X}{j} r^j (1 - r)^{X-j}$ denote the density of a binomial variate j with parameters (X, r). Let $B(z, X, r) \equiv \Sigma_{j=0}^{z} b(j, X, r)$ denote the corresponding cumulative density. Since C is the crime participation rate and since an individual has collected a total of ln observations (n observations in each of the previous l periods), the probability that he will observe a total of X criminals is

$$b(X, ln, C). \tag{27}$$

The actual probability of punishment is now

$$r \equiv R(C, E), \tag{28}$$

where $R_C < 0$ and $R_E > 0$. Therefore, the probability that the individual will observe z or fewer criminals punished, out of X, is

$$B(z, X, r), \tag{29}$$

where $z \equiv z(X, \mathbf{h}, u)$. Thus from (25), it is clear that (29) is the probability that an individual who has observed X criminals will choose to be a criminal. If we combine (27) with (29) and sum over X, his propensity for crime is

$$c(t, T, \mathbf{h}, u) = \sum_{X=0}^{ln} b(X, ln, C) B(z, X, r). \tag{30}$$

Aggregation of (30), according to (3), yields an explicit version of equation (20) for steady-state crime participation rates:

$$C = \frac{1}{L} \sum_{l=0}^{L-1} \sum_{X=0}^{ln} b(X, ln, C) B(z, X, r). \tag{31}$$

Using expression (30), we can also examine the effects of an individual's observations on his propensity for crime. Suppose that the individual observes $n + 1$ persons, rather than n, in each period. This is one of the ways to specify that he has "more" information. Since he observes more persons, the probability that he will observe more criminals is larger because a larger n induces a first-order stochastic improvement in the probability density (27). What is its effect on the individual's propensity for crime?

The following three considerations are important in determining the answer. First, how large is r? A smaller r implies, for instance, that fewer of the additional criminals observed by the individual are likely to be punished. This will affect his p and, thus, his propensity for crime. Second, how large is his relative payoff from crime, u? Third, what is the nature of his initial beliefs? As the definition of z in (29) indicates, the magnitude of u and the nature of initial beliefs will influence how his reservation level will change in response to the number of criminals observed.

IV. Crime Participation Rates in Different Societal Groups

Intergroup differences in crime participation rates have been, and will perhaps remain, a subject of scholarly research as well as of popular controversy. This section examines why crime participation rates might differ across groups, how criminality might spill over across groups, and what some of the channels might be through which a change in the degree of intergroup segregation might affect different groups' crime participation rates. The analysis here considers an economy with two societal groups, but it can be extended to many groups. Superscripts $i = 1$ and 2 denote the variables for the two groups.

Recall that a key feature of the relevant information available to an individual is that a substantial part of it comes to him from his vicinity. To reflect this feature in a multigroup economy, suppose that a significant fraction of the n^i observations that an individual in group i collects in each period come from his own group. Let m^i denote the number of observations that a group i individual collects from the first group. That is, in each period, an individual belonging to the first group collects m^1 observations from his own group; an

individual belonging to the second group collects $n^2 - m^2$ observations from his own group. Thus the larger m^1 is or the smaller m^2 is, the more important is one's own group as a source of information to the individual. If $m^1 = n^1$ and $m^2 = 0$, then the two groups are completely segregated, as far as the information flow is concerned. The characteristics of a group i individual are denoted by the vector $\mathbf{h}^i$ and his relative payoff from crime by u^i. I continue to abstract from intragroup differences in characteristics and payoffs.

Let C^i denote the crime participation rate in group i in a stable steady state. Then, analogous to (20), we can express the steady-state equation system as

$$C^1 = F^1(C^1, C^2, \theta^1), \quad C^2 = F^2(C^1, C^2, \theta^2), \tag{32}$$

where θ^i denotes a parameter affecting individuals in group i. Among such parameters are $\mathbf{h}^i$, u^i, n^i, and m^i.

If the individuals' perceptions are described by Bayesian inference, then we can obtain an explicit version of (32) as follows. First, if α denotes the fraction of the total population that belongs to the first group and if the actual probability of punishment is the same for the members of both groups, then, instead of (28), r is given by $r \equiv R(\alpha C^1 + (1 - \alpha)C^2, E)$. This expression can be generalized, for example, by defining $r^i = R^i(C^1, C^2, E)$ to be the group-specific probability or by defining various intragroup probabilities. Second, instead of z, defined in (29), the reservation level for an individual in group i is now $z^i = z(X, \mathbf{h}^i, u^i)$, reflecting his characteristics and payoffs. Third, we need the counterpart of (27) to describe the probability that a group i individual who has been active for l periods has observed X criminals. Since, in each period, a group i individual collects m^i observations from the first group and $n^i - m^i$ observations from the second, this probability is

$$\phi^i(X, l) \equiv \sum_{j=0}^{lm^i} b(j, lm^i, C^1)b(X - j, ln^i - lm^i, C^2). \tag{33}$$

Using these components, we can derive, in a way analogous to that used to derive (31), the following steady-state equation system:

$$C^i = \frac{1}{L}\sum_{l=0}^{L-1}\sum_{X=0}^{ln^i} \phi^i(X, l)B(z^i, X, r), \quad \text{for } i = 1, 2. \tag{34}$$

Complete Segregation

In this extreme case, the behavior of one group does not affect the other. Since proposition 3 applies to each group in such a case, we obtain the following result.

PROPOSITION 5. Highly segregated groups within a society can have different crime participation rates, even if members of all groups face identical parameters. Therefore, significant differences among the crime participation rates of different groups may coexist with relatively modest differences among their economic fundamentals.

The Spillover of Criminality across Groups

Now consider the more common situation in which there is some intergroup interaction. Then the perceptions of the members of one group are influenced, to some degree, by what individuals in the other group do. Let us examine the following type of "spillover" effects. Suppose that there is a change in a parameter faced by the members of one group, but no change in the parameters faced by the members of another group. What, then, is the impact on the crime participation rate in the latter group?

Let the first-round impact of an increase in past crime participation rates, $\partial F^i/\partial C^j$, be denoted by F^i_j, where $i = 1$ and 2 and $j = 1$ and 2. Using reasoning similar to the one that yielded (17), we obtain $F^i_j > 0$. In combination with the stability properties that the C^i satisfy, this yields the following results (see Sah 1989*b*). First,

$$\operatorname{sgn}\left(\frac{dC^1}{d\theta^i}\right) = \operatorname{sgn}\left(\frac{dC^2}{d\theta^i}\right). \tag{35}$$

Second, suppose that the parameter change is in the neighborhood of the case in which the two groups face the same set of parameters. That is, the perturbation is in the neighborhood of the case in which $F^1_j = F^2_j$. Then

$$\left|\frac{dC^i}{d\theta^i}\right| > \left|\frac{dC^j}{d\theta^i}\right| \quad \text{for } i \neq j. \tag{36}$$

These results are summarized in the following proposition.

PROPOSITION 6. Consider an economy consisting of two societal groups. (i) If a change in a parameter faced by the members of one group raises this group's crime participation rate, then the crime participation rate in the other group also rises because of spillovers, even though the latter group's members have not experienced any change in parameters. (ii) If differences between the parameters faced by the two groups are small, then the change in the crime participation rate of the group whose members face a parameter change exceeds in magnitude the spillover impact on the other group's crime participation rate.

These results hold for all types of parameter changes. For example,

suppose that the relative payoff from crime has increased for the members of the first group. Then, for reasons noted earlier, this group's crime participation rate will rise. In addition, because of intergroup interactions and the resulting change in individuals' perceptions and in the actual probability of punishment, the choices of those in the second group will be altered such that this group's crime participation rate will rise as well. Moreover, if differences in the parameters faced by the members of the two groups are small, then the first group will experience a larger increase in the crime participation rate than the second.

The Effects of a Change in Degree of Intergroup Segregation

For verbal convenience, suppose that members of the first group are "poorer" and that this group's crime participation rate exceeds that of the "richer" group. Now consider a decrease in the degree of segregation resulting from a unit decrease in m^1 and a unit increase in m^2. That is, a poorer person now collects one more observation from the richer group and one fewer from the poorer group. The opposite is the case for a richer person. Then it is more likely that a poorer person will observe fewer criminals and that a richer person will observe more criminals.[8]

The impact of this change on individuals' choices is determined partly by the three considerations described at the end of Section III. There are additional channels of influence as well because the spillovers of the type identified in part i of proposition 6 matter. For instance, if the poorer group's crime participation rate falls because of the change in the perceptions of *its* members, then the spillover will lower the richer group's crime participation rate. On the other hand, if the richer group's crime participation rate rises because of the change in the perceptions of *its* members, then the spillover will raise the poorer group's crime participation rate.

V. Some Extensions

The formulations presented earlier expand comfortably in several directions. Some of these are briefly described here.

[8] This follows from the result that if $C^1 > C^2$, then a larger m^i induces a first-order stochastic improvement in the density ϕ^i, which was defined in (33). See Sah (1989*a*) for more general results of this type.

The Differences in Individuals' Characteristics

These differences are easily incorporated. For example, let $dK(\mathbf{h})$ denote the fraction of each cohort having characteristics represented by the vector $\mathbf{h}$. Then the steady-state equation (31) becomes

$$C = \frac{1}{L}\sum_{l=0}^{L-1}\sum_{X=0}^{ln}\int b(X, ln, C)B(z, X, r)dK(\mathbf{h}).$$

Analogous extensions apply to economies with several groups. An example of a characteristic in which individuals may differ is their initial beliefs concerning the magnitude of r. For particular types of initial beliefs, we can also examine the impact of a change in the distribution of initial beliefs. The case in which the initial beliefs are represented by beta distributions is examined in Sah (1990), where the following result is established: *If more individuals initially have smaller perceived probabilities of punishment, then the subsequent crime participation rate will be higher and the actual probability of punishment will be smaller.*

Payoffs

For brevity, an individual's relative payoff from crime, u, was treated earlier as fixed and the same for all individuals within a group. However, an individual's u might be affected by other variables in the economy. For instance, u may become smaller at higher crime participation rates because of the crowding out of opportunities from crime. One can similarly deal with the effects of the crime participation rate on other variables that have thus far been treated as parameters.

Moreover, the u's may differ for individuals within a group, reflecting (i) age (e.g., because the punishment of adults is often different from that of juveniles); (ii) abilities, wealth, employment, and other determinants of crime versus noncrime opportunities; (iii) tastes, including such aspects as drug addiction, and the discount factors for calculating personal losses from future punishments; and (iv) past crime history, which may affect an individual's productivity in crime (e.g., through learning by doing) as well as his noncrime opportunities (e.g., because of the stigma attached to convicts).

Another issue is the extent to which the availability of the operational knowledge and technology of crime, including its methods and implements, at a location affects its residents' u's. For instance, a greater availability in a neighborhood, which may itself be more likely if the local crime participation rate is high, might influence the future choices of its residents toward greater criminality. The possibility of this effect has also, in part, led researchers to examine the impact of

migration on the crime participation rate. The reason is that one might expect this effect to be weaker in localities subject to a greater force of migration. Currently available evidence on this issue, however, is not conclusive.

An Individual's Choices

This aspect was simplified earlier; the choice in each period was whether or not to be a criminal. However, my analysis applies to other specifications as well, such as those in which an individual chooses from a range of criminal and noncriminal activities that can be undertaken with varying levels of effort within the same duration.

VI. Some Remarks

A long-standing puzzle, especially in the sociogenic literature on crime,[9] has been that even when exposed to nearly identical economic and social environments (e.g., slums, poverty, and unstable homes), only some individuals choose to become criminals while others do not. Further, econometric studies have routinely established the significance of background variables, such as ethnicity and location, in the criminal choice, after controlling for a range of economic variables (e.g., income, education, and intragroup income distribution) and deterrence variables (e.g., the severity of punishment and the resources spent on crime prevention and criminal justice). It has typically not been easy to understand why these patterns should be so. These lacunae have provided a motivation for the present paper.

A different source of motivation is the following lacuna. In accord with what one would expect, individuals' choices concerning crime are influenced by their perceptions of their probabilities of punishment. Moreover, many of the empirically observed patterns of perceptions within and across societal groups invite attention and study. On the other hand, economic analyses that explicitly attempt to incorporate perceptions, including their endogenous determination and their consequences at the economywide level, have largely been missing.

My analysis has endogenized individuals' perceptions concerning their probabilities of punishment, but not their other perceptions that may also be important (e.g., perceptions concerning the penalty schedule). This is partly for brevity. More important, there are critical differences in different categories of perceptions. For example, individuals' perceptions concerning penalties do not, by themselves, alter

[9] See Bureau of Justice Statistics (1983, p. 30) and references therein.

the actual penalties. The actual penalties are altered by changes in the law. In contrast, given a set of laws, the actual probabilities of punishment are determined endogenously, partly as a consequence of individuals' perceptions concerning them. This endogeneity has played an important role in this analysis.

Environmental influences of the kind emphasized in this paper may be important in several contexts other than crime. I have focused on crime here because it is, in itself, a centrally important social issue. Also a meaningful analysis in other contexts would have to be motivated by context-specific considerations, such as what the environmental influences are, who the key economic actors are, and what the specific questions to be examined are. Thus a discussion of different contexts is too broad a topic to be treated here.

A long tradition of social thought has maintained that an individual's environment influences his propensity for crime. Such views can be assessed by using analyses similar to those presented in this paper in which the environment plays an explicit causal role. Such an assessment is important for the public debate on crime. For instance, some social theorists have contended that punishment does not deter crime because its "root cause" is the environment (see Sowell [1980, chap. 9] for a review and criticism of such views). Though this contention is influential, it is not supported by the present analysis, which shows that, although the environment matters, the current crime participation rate will be lower if apprehension and punishment have persistently been more efficacious in the past.

Several implications of the present analysis differ from those that follow from analyses of crime based on static models of individual choice. For example, since the latter do not deal with the consequences of past variables, they may overstate the effects of current policy variables on current crime participation rates. Given past variables, current crime participation rates may be rather insensitive to current policy variables. By the same token, these analyses may understate the effects of current policy variables on future crime participation rates.

This issue is potentially important. Many politicians get elected on planks that emphasize being "tough" on crime. Some of them make genuine efforts at changing the punishment policy, police expenditures, and other measures for fighting crime. Such changes, however, rarely reduce the incidence of crime immediately, or even within the typical tenure of elected politicians. This apparent lack of response is a source of frustration for politicians as well as for law enforcement officials, often leading to a sense of helplessness. Such reactions, though understandable, may be inappropriate if they are caused by an inadequate understanding of the dynamics of crime.

Appendix

Derivation of (7) and (9)

Let $b(j, n, C) \equiv \binom{n}{j} C^j (1 - C)^{n-j}$ denote the density of a binomial variate j with parameters (n, C). Let $B(s, n, C) \equiv \Sigma_{j=0}^{s} b(j, n, C)$ denote its cumulative density. A property of B is

$$\frac{\partial B(s, n, C)}{\partial C} < 0 \quad \text{for } s = 0 \text{ to } n - 1. \tag{A1}$$

Now, $\text{prob}\{x(\tau) \geq s\} = 1 - B(s - 1, n, C(\tau))$. This and (A1) yield (7). The derivation of (9) is analogous.

Derivation of (11) and Evaluation of (14)

Consider the case for which $T = t + 1$; the same logic holds for other T's. Suppress **h**, and denote $x(t)$ by x, $y(t)$ by y, and $r(t)$ by r. Thus, from (5), $c = \text{prob}\{u \geq P(x, y)\}$. Assume that $1 > c > 0$. Define a function $Z(x, u)$ such that $u = P(x, Z(x, u))$. Let $z(x, u)$ denote the largest integer not larger than $Z(x, u)$. Then, using (6) and the definition of z, we obtain

$$z(x + 1, u) \geq z(x, u) \tag{A2}$$

and

$$z(x, u') \geq z(x, u) \quad \text{for } u' > u. \tag{A3}$$

Also, (6) and the definitions of z and c yield $c = \text{prob}\{y \leq z(x, u)\}$. Thus (10) can be expressed as

$$c = \sum_{x=0}^{n} \text{prob}\{x\} \cdot B(z(x, u), x, r). \tag{A4}$$

Define sets I_1, I_2, and I_3 such that $x \in I_1$ if $z(x, u) \geq x$, $x \in I_2$ if $x - 1 \geq z(x, u) \geq 0$, and $x \in I_3$ if $z(x, u) < 0$. The cumulative density B has the property that $B(z, x, r) = 0$ if $z < 0$ and $B(z, x, r) = 1$ if $z \geq x$. Using these, we can restate (A4) as

$$c = \sum_{x \in I_1} \text{prob}\{x\} + \sum_{x \in I_2} \text{prob}\{x\} \cdot B(z(x, u), x, r), \tag{A5}$$

where B on the right-hand side is positive but smaller than one. Make the reasonable assumption that I_2 is nonempty. In combination with (A1), the derivative of (A5) with respect to r yields the first part of (11).

Next, consider an increase in u to u'. From (A3), (A5), and the definitions of the I's, it can be verified that the induced changes in these sets cannot decrease c. Now make the assumption, which can be weakened, that the inequality in (A3) is strict for at least one x belonging to I_2. This yields the second part of (11).

To evaluate (14), write $z(x, u)$ as $z(x)$. Define $k(x) \equiv z(x + 1) - z(x)$ and $\delta(x, r) \equiv B(z(x) + k(x), x + 1, r) - B(z(x), x, r)$. From (A2), $k(x) \geq 0$, and it is an integer. From (7), an increase in $C(t)$ induces a first-order stochastic improvement in the probability density of x. Hence, from (A4) and from a standard result concerning first-order stochastic dominance, it follows that a sufficient but not necessary condition for $\partial c / \partial C(t) \geq 0$ is that $\delta(x, r)$ be nonneg-

ative for all x. Next, we evaluate δ, using the following properties: if $r \to 0$, then $B(z, x, r) \to 0$ if $z < 0$ and $B(z, x, r) \to 1$ if $z \geq 0$. For a given x, there are only three possibilities: (i) $z(x) \geq 0$ (and hence $z(x) + k(x) \geq 0$), (ii) $z(x) < 0$ and $z(x) + k(x) < 0$, and (iii) $z(x) < 0$ and $z(x) + k(x) \geq 0$. Thus, for all values of x, $\delta(x, r)$ tends to a nonnegative number as $r \to 0$. In turn, the conclusion noted in the text follows.

References

Andreano, Ralph, and Siegfried, John J., eds. *The Economics of Crime.* New York: Wiley, 1980.

Becker, Gary S. "Crime and Punishment: An Economic Approach." *J.P.E.* 76 (March/April 1968): 169–217.

Becker, Gary S., and Landes, William M., eds. *Essays in the Economics of Crime and Punishment.* New York: Columbia Univ. Press (for NBER), 1974.

Block, Michael K., and Heineke, John M. "A Labor Theoretic Analysis of the Criminal Choice." *A.E.R.* 65 (June 1975): 314–25.

Bureau of Justice Statistics. *Report to the Nation on Crime and Justice: The Data.* Washington: U.S. Dept. Justice, 1983.

———. *Report to the Nation on Crime and Justice.* 2d ed. Washington: U.S. Dept. Justice, 1988.

Carter, Ronald L., and Hill, Kim Q. "Criminals' and Noncriminals' Perceptions of Urban Crime." *Criminology* 16 (November 1978): 353–71.

Ehrlich, Isaac. "Participation in Illegitimate Activities: A Theoretical and Empirical Investigation." *J.P.E.* 81 (May/June 1973): 521–65.

Heineke, John M., ed. *Economic Models of Criminal Behavior.* Amsterdam: North-Holland, 1978.

Hirsch, Morris W., and Smale, Steve. *Differential Equations, Dynamical Systems, and Linear Algebra.* New York: Academic Press, 1974.

Klevorick, Alvin K. "Legal Theory and the Economic Analysis of Torts and Crimes." *Columbia Law Rev.* 85 (June 1985): 905–20.

Montmarquette, Claude, and Nerlove, Marc. "Deterrence and Delinquency: An Analysis of Individual Data." *J. Quantitative Criminology* 1 (March 1985): 37–58.

Nisbett, Richard E., and Ross, Lee. *Human Inference: Strategies and Shortcomings of Social Judgment.* Englewood Cliffs, N.J.: Prentice-Hall, 1980.

O'Donnell, John A., et al. *Young Men and Drugs: A Nationwide Survey.* Research Monograph no. 5. Rockville, Md.: Nat. Inst. Drug Abuse, 1976.

Parker, Jerry, and Grasmick, Harold G. "Linking Actual and Perceived Certainty of Punishment." *Criminology* 17 (November 1979): 366–79.

Piliavin, Irving, et al. "Crime, Deterrence, and Rational Choice." *American Sociological Rev.* 51 (February 1986): 101–19.

Pyle, David J. *The Economics of Crime and Law Enforcement.* New York: St. Martin's, 1983.

Richards, Pamela, and Tittle, Charles R. "Socioeconomic Status and Perceptions of Personal Arrest Probabilities." *Criminology* 20 (November 1982): 329–46.

Sah, Raaj K. "Comparative Properties of Sums of Independent Binomials with Different Parameters." *Econ. Letters* 31 (November 1989): 27–30. (*a*)

———. "Results for Comparative Statics of Non-linear Discrete Dynamic Systems of Higher-Order." Working paper. New Haven, Conn.: Yale Univ., 1989. (*b*)

———. "Social Osmosis and Patterns of Crime: A Dynamic Economic Analysis." Discussion Paper no. 609. New Haven, Conn.: Yale Univ., Econ. Growth Center, 1990.

Schmidt, Peter, and Witte, Ann D. *An Economic Analysis of Crime and Justice: Theory, Methods, and Applications*. Orlando, Fla.: Academic Press, 1984.

Sowell, Thomas. *Knowledge and Decisions*. New York: Basic Books, 1980.