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by
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Deterrence and Incapacitation: Control Theory Applied to Crime

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ROUGH DRAFT

ABSTRACT

Crimes differ by seriousness and punishments differ by severity. The problem addressed in this paper is to construct a schedule of punishments for offenses of increasing seriousness which will be optimal from the viewpoint of deterrence and incapacitation. I assume that fines and incarceration are the two forms of punishment. I prove that the optimal fine for the most serious offense actually committed is the maximum fine which the offender can bear. I also prove that incarceration should not be used until the ability to deter by fines is exhausted, i.e. imprisonment should not be used except in conjunction with the maximum fine. I discuss conditions under which enforcement effort (arrest and prosecution) should be greater for mild offenses than for serious offenses. Finally, I show that substituting fines for imprisonment as punishment for mild offenses does not influence the total number of crimes committed by repeat offenders. The theoretical results are proved by using mathematical control theory. The results are compared to the actual practices of legal institutions. The main policy conclusion is that fines are underutilized in America.
Deterrence and Incapacitation: Control Theory Applied to Crime*

Some crimes are economic in the sense that they are committed after assessment of the risk and the potential gain. Any desired level of deterrence for such crimes can be achieved by policies which set the risk at the appropriate level. The risk depends upon the probability and magnitude of punishment.

Mathematical economics is well suited for theorizing about policies which influence the risk faced by offenders. In this paper mathematical control theory is used to explore the relationship between the seriousness of the offense, the severity of the punishment, and the probability that an offender will be punished.

The full cost of crime includes the harm suffered by its victims, the harm imposed upon offenders by punishing them, the cost of enforcement (e.g. police and prosecution), and the cost of punishment to the state (e.g. prison costs). An optimal schedule of punishment minimizes the full cost of crime. I prove that the optimal fine for the most serious offense actually committed is the maximum fine which the offender can bear. I also prove that incarceration should not be used except in conjunction with the maximum fine. In other words, the ability to pay a fine should be exhausted before resorting to incarceration.

The "proofs" assume that the policy objective is to minimize the full cost of crime and offenders respond rationally to risk. The reader may object that many criminals are irrational and the objective of public policy is not minimizing the full cost of crime. The proofs are robust with respect to many changes in the assumptions. I show that altering

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some of the behavioral or philosophical assumptions does not invalidate the proofs.

There is an obvious policy conclusion to draw from the theory, namely that the ability of offenders to pay fines should be exhausted before resorting to incarceration. For example, it does not make sense to sentence a person to jail for seven days and exact no fine, if the person has the ability to pay a fine. In many European countries a system of day fines has replaced jailings for a broad class of offenses, including some felonies. Our theoretical conclusions generally support the reliance on fines as punishment.

Proving these propositions involves a technical innovation in deterrence theory, which can be explained by analogy to the theory of taxation. A simple exercise is to find the optimal tax rate on a consumer good, e.g. the optimal tax per gallon of gasoline.\(^1\) The exercise is simple because everyone pays the same tax on each unit of the consumer good which he purchases, regardless of how many units he purchases. There is only one tax rate. A more complicated exercise is to find the income tax schedule which is optimal.\(^2\) This exercise is more complicated because tax rates are different for different income levels. Constructing a schedule of punishments for offenses differing in seriousness is like constructing an income tax schedule, not like assigning a tax rate to gasoline. Control theory is the best mathematical approach to theorizing about tax or punishment schedules. To my knowledge this is the first paper applying control theory to punishment schedules.
Part I of the paper develops the argument through the use of graphs, but without mathematics. Parts II and III use control theory to prove the propositions discussed in Part I. The reader who is not mathematically inclined may wish to skip Parts II and III. Part IV discusses the interpretation and limits of the propositions proved graphically in Part I. Part V compares the theoretical conclusions to facts about the penal system and tries to reach some policy conclusions. The paper ends with a summary and some philosophical musings.
I. Results Explained Graphically

The main proposition which I wish to prove is that the ability to pay a fine should be exhausted before resorting to incarceration. In other words, imprisonment should never be used except in conjunction with the maximum fine. It is easy to see why this proposition is true. If an offender is imprisoned without also exacting the maximum fine, then the jail sentence could be reduced and the fine increased in such a way that he would perceive the severity of the punishment to be unchanged. If the severity of the punishment were unchanged, then the punished offender would not be any worse off for the change. Furthermore, the deterrence of crime would be the same, so victims would not be any worse off. However, the state could save a lot of money by substituting a cheap penalty (fines) for an expensive penalty (imprisonment). The punishment schedule is not optimal unless the opportunities for substitution of fines for imprisonment are exhausted. The opportunities for substitution are exhausted when imprisonment is not used except in conjunction with the maximum fine.

Many previous writers have expressed a preference for fines over imprisonment. To my knowledge no one has drawn the conclusion that imprisonment should not be used except in conjunction with the maximum fine which the offender can pay.

There may be some classes of offenses for which jail is considered to be an inappropriate punishment. My second proposition states that the optimal schedule of fines will assess the maximum fine which the offender can bear if he commits the worst possible offense among such offenses. The explanation of this proposition is straightforward. Deterrence depends upon the probability and severity of punishment. If the worst possible offense is not punished by the maximum fine, then the severity of punishment could be increased and the probability decreased without changing the level of deterrence. This substitution would not effect the amount of
crime. However, the state could save money by substituting a cheap penalty (fines) for expensive enforcement (police and prosecutor). The punishment schedule is not optimal unless the opportunities are exhausted for substituting fines for enforcement. The opportunities are exhausted when the worst possible offense is punished by the maximum fine.

Previous models examined one kind of crime in isolation and concluded that the optimal fine for that crime is the maximum fine which the offender can bear. Rather than examining one kind of crime, I examine crimes ranked by seriousness. My formulation leads to the conclusion that the most serious crime should be punished by the maximum fine, but mild offenses should be punished by lower fines.

The purpose of the first section of Part I is to explain my two propositions graphically. First an account is given of the behavior of potential offenders and then the characteristics of the optimal punishment and enforcement schedules are derived.

For purposes of exposition the abstract propositions are illustrated by an example of embezzlement. Embezzlement is intuitive because the payoff is monetary, but the argument also applies, say, to traffic offenses or assault. Suppose that a company keeps certain records on a monthly basis and selects one month for auditing each year. There is a bookkeeper who sometimes has the opportunity to embezzle funds by fiddling the records. He will get caught if the fiddled records are audited. My task is to describe the embezzler's behavior and compute the schedule of punishments which is optimal for deterring such people.

The bookkeeper has wealth or income from legitimate sources which is denoted A. The amount which he embezzles is denoted z. Thus his total income from legitimate and illegitimate sources is \( A + z \). If his crime goes unpunished, then he gets to consume his full income, \( A + z \). If his crime is punished, then some of his income may be taken from him in the form
of a fine. He may also be imprisoned, but the discussion of imprisonment comes later. The fine will be an increasing function of the seriousness of his offense. It is convenient to assume that the amount embezzled, $z$, measures the seriousness of the offense. Thus the fine is an increasing function of the amount embezzled, denoted $f(z)$. If he is punished, then his consumption will be $A+z-f(z)$.

Let $p(z)$ be the probability that an offense of seriousness $z$ will be punished and let $1-p(z)$ be the probability of escaping punishment. The embezzler stands to enjoy $A+z$ with probability $(1-p)$ and $A+z-f(z)$ with probability $p$. This is the gamble faced by the bookkeeper when he decides how much to embezzle. Figures 1 and 2 illustrate the gamble graphically, as I shall explain.

Embezzling, like any form of work, requires effort. The effort is exerted in order to achieve a higher level of consumption. The rate at which effort and consumption tradeoff against each other is illustrated by the indifference curves (convex lines) in Figures 1 and 2. Each of these curves represents combinations of effort and consumption at which the bookkeeper is indifferent, e.g. the bookkeeper would just as soon have the low level of consumption and effort at point $\beta$ in Figure 1 as the high level of consumption and effort at point $\gamma$. If the bookkeeper were certain that he would not be punished, then he would embezzle the amount of money $\bar{z}$ shown in Figure 1. This point is located where the budget line (straight line) is tangent to an indifference curve. The point $\bar{z}$ is chosen because it yields the highest utility attainable along the budget line $A+z$. 
The budget line in Figure 2 shows the consumption $A+z-f(z)$ which the embezzler enjoys if he is punished. In order to deter effectively, the fine must bite into the offender's legitimate income. In other words, the amount exacted from the embezzler should be enough to compensate the victim and then some. If we define the fine $f(z)$ to include victim's compensation, then the fine $f(z)$ will exceed the amount embezzled $z$. This is illustrated in Figure 2 by the fact that the budget line $A+z-f(z)$ lies below $A$. The budget line lies below $A$ because the punished offender's consumption is less than his legitimate income, since part of the legitimate income is taken by the fine.

If the offender knew that he would be punished, then he would not commit the offense. This is illustrated by the fact that the budget line in Figure 2 touches the highest indifference curve at the point $A$ on the vertical axis, where $z=0$. If punishment were certain, then the potential embezzler would maximize his utility by setting $z=0$.

The bookkeeper faces arrest and conviction with probability $p$, and he escapes punishment with probability $1-p$. If $p=1$, then he will choose $z=0$ as depicted in Figure 2. If $p=0$, then he will choose $z=\bar{z}$ as depicted in Figure 1. For intermediate probabilities, he will choose a value of $z$ greater than zero and less than $\bar{z}$. The exact choice of $z$ will depend upon the probability $p$ and the schedule of punishment.

The maximum fine which the embezzler can pay equals his total income from legitimate and illegitimate sources, $A+z$. If the maximum fine is assessed, then the punished offender's consumption is nil, or equivalently, the budget line is nil, $0=A+z-f$. Graphically, consumption is nil when the budget line touches the horizontal axis. In Figure 2 the maximum fine is assessed for all offenses at least as serious as $z^*$.
FIG 1

CRIMINAL EFFORT OR SERIOUSNESS OF OFFENSE (MEASURED IN DOLLARS EMBEZZLED)
FIG 2

CONSUMPTION

A

\( A + Z - f(Z) \) (BUDGET LINE)

O \( \frac{Z}{Z} \) \( Z^* \) \( \hat{Z} \)

CRIMINAL EFFORT OR SERIOUSNESS OF OFFENSE
(MEASURED IN DOLLARS EMBEZZLED)
If punishment is imposed beyond the maximum fine, then it must take some form other than a fine. Additional punishment might take the form of incarceration. In this model the crucial features of incarceration are that it extends punishment beyond the limits imposed by bankruptcy, and it is expensive for the government.

I would like to be able to measure the total punishment by adding together the fine and incarceration. Fines are measured in dollars and incarceration is measured in days spent in jail. It is convenient to convert incarceration into money equivalents for the punished person, so that incarceration and fines can be added. A variety of interpretations of the money equivalent of a day in jail are possible. The money equivalent might be measured by the amount which a person would be willing to pay in order to avoid a day in jail. If the person lacks wealth, then the money equivalent could be measured by the earnings from future labor that he would give up to avoid one day in jail. If the person lacks earning ability, then the money equivalent could be measured by the amount that he would give up to avoid a day in jail if, contrary to fact, he possessed wealth. The idea of a money equivalent to incarceration is troublesome, but the exact interpretation does not matter much to our theorems.  

Let \( y(z) \) represent the schedule of imprisonment measured in money equivalents. The total punishment is the fine plus incarceration, or \( f(z) + y(z) \). The total consumption in the event of punishment is total income less total punishment, or \( A+2-f(z)-y(z) \). Incarceration makes it possible to extend the budget line below the horizontal axis, as depicted in Figure 3.

Augmenting fines with incarceration does not change the logic of the embezzler's decision. He would still embezzle \( \bar{z} \) if he were certain to go unpunished and 0 if he were certain to be punished. He still must
Fig 3

CONSUMPTION

SERIOUSNESS OF OFFENSE

$A + z - f(z) - y(z)$
balance the additional consumption if unpunished against the possible punishment. The only difference is that the punishment is now $f(z) + y(z)$, rather than merely $f(z)$.

The schedule of punishments is directed against a whole class of potential offenders similar to our embezzler. Offenders are assumed to differ according to their earnings from investing effort in crime (i.e. their criminal wage), the difficulty of apprehending them, and their intrinsic liking or disliking for crime. My next task is to construct a schedule of punishments which is optimal for deterring a whole class of potential offenders.

The social objective is to choose the schedule of punishment and enforcement effort to minimize the full cost of crime. The full cost includes the harm suffered by victims, the harm imposed upon offenders by punishing them, the cost of enforcement, and the cost of punishment. These costs must be weighted, added together, and minimized.

The first proposition which I wish to prove is that the ability to pay a fine should be exhausted before resorting to incarceration. In other words, incarceration should never be used except in conjunction with the maximum fine.

It is easy to explain why this proposition is true. Suppose that an embezzler is indifferent between a sentence of thirty days in jail with a $5,000 fine, or a sentence of seven days in jail with a $10,000 fine. Since the embezzler is indifferent, the harm imposed upon him by the punishment will be the same under either sentence. Since the harm is the same, he will be deterred equally by either punishment. Since deterrence is equal, the amount which he will embezzle will be the same and the harm suffered by victims will be the same. However, the fine is much cheaper
for the state to administer than the jail sentence. Thus the full cost of crime will be less if the second sentence is used instead of the first sentence.

Generalizing, if a fine can be substituted for incarceration so that the punished criminal is indifferent, then the state can substitute a cheap penalty for a costly penalty without affecting the harm suffered by victims or punished offenders. Minimizing the full cost of crime requires carrying out this substitution until the opportunities are exhausted. If incarceration is combined with a fine which is less than the maximum which the offender can bear, then the opportunities for substitution have not been exhausted.

The argument is illustrated graphically in Figures 4A and 4B. The solid line is the punished offender's budget line. The budget line indicates the consumption left to him after subtracting punishment from his total income. The punishment includes the fine and the income equivalent of incarceration. In order to separate the fine from incarceration, a dotted line has been added. The dotted line represents the punished offender's total income less the fine. Thus the vertical distance between the dotted line and the solid line represents the income equivalent of incarceration, i.e. the amount by which consumption is reduced by incarceration.

In zone 1 of Figure 4A, the dotted line and solid line are the same, indicating that these minor offences are not punished by incarceration. In zone 2 the solid line lies below the dotted line, indicating that these
offenses are punished by a fine and incarceration. In zone 3 the dotted line is along the horizontal axis, indicating that the maximum fine is assessed. The fine is maximum along the horizontal axis because income less the fine is nil. In zone 3 the maximum fine is combined with incarceration.

Zone 2 of the punishment schedule depicted in Figure 4A does not satisfy the optimality condition because incarceration is used in conjunction with a fine which is not the maximum which the offender can bear. This deficiency is corrected in Figure 4B. Figure 4B has been obtained from Figure 4A by substituting additional fines for incarceration in zone 2. The substitution was carried out until opportunities were exhausted, so that incarceration is not used except in conjunction with the maximum fine.

In zone 1 of Figure 4B the dotted line is the same as the solid line, indicating that the entire punishment is the fine. In zone 3 of Figure 4B, the dotted line is the same as the horizontal axis, indicating that the maximum fine is levied, and the solid line lies below the dotted line, indicating that the punishment in zone 3 includes incarceration. Notice that zone 2, which is inefficient, has disappeared from Figure 4B.

Figures 4A and 4B have been constructed so that the total punishment is the same. The total punishment is the same because the solid budget line, which indicates total income less the total punishment, is the same in both figures. Since punishment is the same, the harm done to punished offenders and the amount of crime will be the same. Since the amount of crime is the same, the harm done to victims of crime will be the same. However, the punishment schedule in Figure 4A relies more on incarceration and 4B relies more on fines.
Under certain conditions, the total incarceration can be represented by the shaded area. Notice that the shaded area above the horizontal axis in Figure 4A, which is cross-hatched, disappears from Figure 4B. This cross-hatched area represents the incarceration under the suboptimal schedule which is replaced by fines under the optimal schedule. The optimal schedule saves costs of incarceration indicated by the cross-hatched area, without changing the harm suffered by the victims of crime or punished offenders.

There are some classes of offenses for which incarceration is deemed inappropriate. If incarceration is not used for a certain class of offenses, then what is the optimal fine? My second proposition states that the optimal schedule of fines will assess the maximum fine which the offender can bear if he commits the worst possible offense.

The explanation for the proposition is simple. Suppose that the worst possible offense is not punished by the maximum fine. Increasing the fine will increase the amount of deterrence at little or no cost to the state. This increase in costless deterrence can substitute for costly deterrence. By hypothesis there is no scope to substitute fines for costly imprisonment. However, it is possible to substitute fines for costly enforcement effort, such as expenditure on police and prosecutors.

If the increase in the fine is offset by exactly the right decrease in enforcement effort, then the amount of crime will be the same. Since the amount of crime is the same, the amount of harm suffered by its victim's will be the same. Furthermore, the cost of enforcement will be reduced without any change in the cost of punishment. Thus the full cost of crime will be reduced, except perhaps for the harm imposed upon offenders.
There is a problem over how to measure the harm suffered by offenders. Offenders at large are indifferent between risking a severe fine with small probability or risking a small fine with large probability. If the harm imposed upon offenders is measured by the preferences of offenders at large, then there is no change in the welfare of offenders. (This is probably the correct approach from a utilitarian viewpoint.) However, if the harm imposed upon offenders is measured by the preferences of convicted offenders, then more severe fines make them worse off. Thus the proposition that fines should be substituted for enforcement effort where possible to reduce the full cost of crime is true if the cost to offenders is measured by risk to which they are exposed, not the punishment which convicted offenders receive.

The basic argument is illustrated graphically in Figure 5. \( \hat{\omega} \) represents the most serious offense which it is possible to commit. Suppose that the actual fine schedule were the one implicitly represented by B. If the fine were increased by shifting the budget line down to C, then the person committing the offense \( \hat{\omega} \) would face a more severe punishment. Everyone committing a lesser offense would also face a more severe punishment. The fine is more severe inframarginally under schedule B than C for every offense, and it is more severe marginally for every offense except \( \hat{\omega} \). The marginal punishment for \( \hat{\omega} \) is of no consequence since by assumption it is impossible to commit a more serious offense. Thus the deterrence of crime will be increased by shifting from B to C. The increase in the severity of the fine can be offset by a reduction in en-
forcement effort which holds deterrence constant. Since deterrence is constant, the victims of crime are not worse off and the criminals are exposed to the same risk. However, the cost of enforcement is reduced without any increase in the cost of punishment. Thus the full cost of crime under schedule C is lower than under schedule B.

Could the full cost of crime be lowered still farther by shifting the punishment schedule down from C to D as in Fig. 6? Perhaps. If the schedule shifts from C down to D, then a "corner" is created at the point 2. This corner in the punishment schedule means that there is no incremental penalty for offenses more serious than 2. Presumably the shift from C to D will cause mild offenders to reduce their crimes and serious offenders to increase their crimes. On balance the full cost of crime might rise or it might fall. However, our proposition that the maximum fine is assessed for the most serious offense 2 is true under both schedules C and D.

Enforcement Effort

We have discussed two propositions: Incarceration should not be used except in conjunction with the maximum fine, and the maximum fine should be levied for the most serious offense which it is possible to commit within classes of offenses not punishable by incarceration. Now we consider the optimal expenditure on enforcement. Enforcement effort by police and prosecutors can be targeted at particular offenders. Greater effort will increase the probability that the targeted offenders are punished. Calibrating the probability of punishment is similar to calibrating the severity of punishment. Our goal is to characterize the schedule of probabilities which minimize the full cost of crime.

Upon first consideration it might seem that more serious crimes would be punished with higher probability, just as more serious crimes are
FIG 6

INCOME

A

O

CRIMINAL EFFORT

C

D

Z

Z
punished by higher fines. For example, we might expect that bookkeepers who embezzle $10,000 will find escaping punishment more difficult than bookkeepers who embezzle $1,000, because more serious crimes will attract more enforcement effort. If this line of reasoning were correct, then the optimal probability of punishment would increase with the seriousness of the crime as depicted by schedule A in Figure 7.

But recall that the optimal punishment increases with the seriousness of the crime, thus providing more deterrence for serious crimes than for minor crimes. Since heavy punishments are unavailable for mild offenses, perhaps minor crimes must be deterred by a higher probability of punishment than serious crimes. If this line of reasoning were correct, then the optimal probability of punishment would decrease with the seriousness of the crime as depicted by schedule B in Figure 7.

Which line of reasoning is correct? I have been unable to discover proofs which offer a satisfactory answer to this question, but there is one intriguing theorem. It is possible to prove that the optimal allocation of enforcement effort is decreasing with the seriousness of the offense for the worst offense actually committed. At the top of the scale of seriousness, the probability schedule slopes down like B in Figure 7. Thus the probability of punishment would increase for the most serious offender if he decreased the seriousness of his offense.

The explanation of this proposition is subtle. If the worst offender reduces the seriousness of his offense, then he faces a less severe punishment. Suppose contrary to our theorem that he would also face a lower probability of punishment. Then it is a fact about our model that he would
FIG 7

PROBABILITY OF PUNISHMENT

SERIOUSNESS OF OFFENSE

O

A

B

Z
reduce the seriousness of his offense. But this argument can be repeated again for the offense of reduced seriousness. Thus the distribution of offenders would unravel and no one would choose to commit an offense. In technical language, we can prove that the worst offender's preferred offense is a corner solution when the punishment and enforcement schedule is optimal, unless the probability of punishment decreases with the seriousness of his offense.

It seems unlikely that the cost minimizing schedule of punishment and enforcement would result in no offenses. If the optimal punishment and enforcement schedules induce a distribution of offenses, rather than no offenses, then an implication of the model is that the probability of punishment for the worst offender would increase if he committed a less serious offense.

This theorem and its proof may be a consequence of special features of our mathematical model which would disappear in a more general model. Certainly this theorem is not so robust as the propositions concerning the maximum fine and incarceration. However, the theorem does suggest the intriguing possibility that the optimal probability of punishment might decrease with the seriousness of the offense over some range of offenses. I will return to this issue later.

Incapacitation

The most important conclusion from the first model was that fines should replace incarceration whenever this can be accomplished without loss of deterrence. If deterrence is the same, then the amount of crime would be the same, according to the model. But this argument did not take account of the fact that imprisonment incapacitates offenders and fines do not. An offender is unable to repeat his crime during the duration
of his imprisonment, but he can repeat immediately after payment of a fine. Would there be more crime if fines replaced imprisonment, even if deterrence were the same, because offenders would not be incapacitated?

In order to answer this question it is necessary to revise the model and consider repeat offenders. When the model is revised, the conclusion can be reached that replacing incarceration with fines of equal deterrence value does not affect the total number of crimes. The repeat offender who is punished by fines for his first several offenses, rather than equivalent incarceration, will not commit more crimes over his career as a criminal, but he will commit them at a younger age. The conclusion of the model of incapacitation is that greater reliance upon fines will affect the timing of crimes but not the number of crimes.

The argument for this conclusion is simple. Potential offenders decide whether to commit an offense by balancing the risk of punishment against the gain. An offense is committed when the gain exceeds the risk of punishment. The two most important variables in sentencing are the seriousness of the offense and the number of previous offenses.\(^7\) As a repeat offender acquires a record of previous arrests and convictions, the severity of the punishment increases for an offense of given seriousness. For the first offense, the gain may exceed the risk of punishment. After enough arrests the risk of punishment will exceed the gain. At the point where the risk of punishment exceeds the gain, the criminal "drops out" and stops committing crimes. Criminals differ according to the gain which they derive from an offense, so different criminals drop out after different numbers of offenses.

This argument is illustrated graphically in Figure 8. The number of offenses, denoted \(z\), is indicated by the horizontal axis. The courts imposc
more severe punishments for repeat offenses. Thus the typical offender's risk from an additional offense is much larger if he has previously committed offenses. This fact is indicated by the curve denoted R for risk in Figure 8, which rises at an increasing rate. The gain G from committing the same offense is approximately the same no matter how often it is repeated, so the lines denoted G are horizontal. \( G_1 \) is the first offender's gain and \( G_2 \) is the second offender's gain. Some offenders gain more than others from the same offense, which is why \( G_1 \) lies above \( G_2 \). From the graph we see that the first offender will commit 10 offenses and the second offender will commit 7. Additional offenses by either would involve more risk than gain.

In Figure 8, the risk is determined by the severity and probability of punishment. If incarceration is replaced by a fine of equivalent severity, then the risk will be the same. Since the risk is the same, the offender will repeat the same number of times before he drops out. Substituting fines for incarceration will not influence the total number of crimes committed so long as the severity of the punishment schedule is unchanged. Incapacitation by incarceration merely slows the speed at which the repeat offender reaches the punishment level at which he drops out.

The model of deterrence developed at length earlier in the paper is very similar to the model of incapacitation which we are now discussing. The most salient difference is that the first model assumes that offenders choose how serious the crime will be, whereas in the second model the offenders choose how many times to repeat the same crime. There is not much
structural difference between the models, except \( z \) is interpreted as the seriousness of the offense in the first model and the number of offenses in the second model.

Since the models are similar, the same theorem can be proved about the desirability of fines. Specifically, repeat offenders should not be incarcerated as long as they are able to pay fines.

This theorem is proved by repeating the previous proof. Assume that an offender is fined less than the maximum amount which he can pay and also incarcerated. Now increase the fine and reduce the incarceration in such a way that the offender considers the severity of the punishment to be unchanged. Since the severity of the punishment is the same, the risk born by the offender is the same. Since the risk is the same, the offender will repeat the same number of offenses before dropping out. Since he repeats the same number of offenses, and the severity of the punishment is unchanged, there is no change in the harm done to offenders by punishment. Since the number of crimes is unchanged, the harm suffered by the victims of crime is unchanged. However, the cost to the state of punishing offenders is reduced. Therefore, substituting the fine for equivalent incarceration reduces the full cost of crime. The substitution must proceed until the opportunities are exhausted in order to achieve an optimal punishment schedule.
II. Control Formulation of Deterrence

In this section I use control theory to prove the propositions discussed in Part I. The nonmathematical reader may skip to Part IV. The behavior of the criminal will be described and then the government's optimization problem will be solved. The propositions are proved by manipulating the necessary conditions for an optimum.

The criminal controls the amount of effort or labor which he devotes to crime. The wage from criminal activity, or the rate at which criminal labor is converted into income, is denoted \( n \). Criminal income is denoted \( z \). Thus the criminal's labor or effort equals \( z/n \).

The criminal derives utility from leisure and consumption. Leisure diminishes with criminal effort \( z/n \). Consumption is denoted \( x \). Different criminals may have different degrees of aversion or attraction to crime. I assume that criminals with the same wage have the same aversion or attraction to crime. Thus the criminal's utility is written

\[
u = u(-z/n,x,n)\]

Crime risks punishment with probability \( p \). Punishment takes the form of a fine \( f \) or imprisonment \( y \). Consumption will be higher if the offender is unpunished than if he is punished. Let consumption when unpunished be denoted \( x_1 \). Let consumption when punished, i.e. income net of the fine, be denoted \( x_2 \). A crucial assumption for one of our theorems is that imprisonment can be measured in income equivalents and added to consumption in determining utility. Consumption net of imprisonment is given by \( x_2 - y \). Thus the criminal's expected utility is written

\[
U = (1-p)u(-z/n,x_1,n) + pu(-z/n,x_2-y,n)\]
The criminal's total income equals his criminal income $z$ plus his legitimate income $A$. If unpunished, then consumption equals total income: $x_1 = A + z$. If punished, there is a fine $f$ and imprisonment $y$. Consumption net of fine and imprisonment is written $x_2 - y = A + z - f - y$. The fine and imprisonment are increasing functions of the seriousness of the offense: $f = f(z)$ and $y = y(z)$, where $f' > 0$ and $y' > 0$.

The probability of punishment depends upon the seriousness of the offense and the type of offender: $p = p(z, n)$. If criminals with higher criminal wages are intrinsically more difficult to catch, then $p_2 < 0$. The sign of the derivative of $p(\cdot)$ with respect to $z$ is determined by public policy, as will be explained. Thus the individual's maximization problem can be written

\begin{equation}
\max_{x_1, x_2, y} \quad U = (1-p)u(-z/n, x_1, n) + pu(-z/n, x_2 - y, n)
\end{equation}

subject to

\begin{align*}
p &\geq p(z, n) \\
x_1 &\leq A + z \\
x_2 &\leq A + z - f(z) \\
y &\geq y(z).
\end{align*}

Indicate the optimal values by the symbol $^*$ and write the expected utility:

\begin{equation}
v_n = U(z^*, p^*, x_1^*, x_2^* - y^*, n).
\end{equation}

This expression can be inverted in its first argument in order to obtain

\begin{equation}
z_n = z(v, p, x_1, x_2 - y, n).
\end{equation}

The government chooses the schedule of punishments $f(z)$ and $y(z)$ in order to minimize the full cost of crime. The cost of crime $z$ to its
victims is denoted c·z. The cost of incarceration y to the state is denoted k·y. If the probability of punishment is p, then the expected cost of incarceration is pk'y. The probability of punishment was written p=p(z,n).

Let \( w(z) \) indicate the expenditure on enforcement for each offender committing crime z. Rewrite \( p(\cdot) \) in the form \( p=p(w(z),n) \), where the function is increasing in \( w \). Invert to obtain \( w=w(p,n) \). Let \( h_n \) be the density of n-type criminals. The cost of crime to its victims and the state for offenders of all types can be written

\[
\begin{align*}
&\sum_{n=1}^{N_2} \left[ w_n + pk'y_n + cz_n^2 - pf(z_n) \right] h_n d_n. \\
&\text{prison fine enforcement victims}
\end{align*}
\]

This expression omits the value of crime to criminals. The benefit of crime to criminals is their expected utility \( v_n \). Let \( G \) be any increasing function which converts utils into dollars. For example, \( G \) could be the usual efficiency standard in cost benefit analysis, or \( G \) could be a social welfare function.\(^{10} \) By incorporating \( G(v_n) \) into the objective,

the final form of the government's objective can be written

\[
\max_{\theta_n} \sum_{n=1}^{N_2} \left[ G(v_n) - w_n - pk'y_n + cz_n^2 - pf(z_n) \right] h_n d_n.
\]

Some transformations are needed to make this problem suitable for the application of control theory. The first transformation involves obtaining a differential equation for the criminal's utility. By differentiating \( v_n \) with respect to \( n \) and using the first order conditions for individual utility maximization, we obtain

\[
\frac{d v_n}{d z_n} = \left[ u(-z/n, x_2, y, n) - u(-z/n, x_1, n) \right] \frac{w_2}{w_1}.
\]

(4)

\[
+ \left[ (1-p)u_1(-z/n, x_1, n) + pu_1(-z/n, x_2, y, n) \right] z/n^2.
\]

Satisfaction of the first order conditions imply that this differential equation is true. I follow the usual approach in the optimal income tax
literature by assuming that the converse is true. As a consequence I can treat \( v_n \) as a state variable whose rate of change is specified by the preceding differential equation.

The government chooses the punishment schedules \( f(z) \) and \( y(z) \), and the enforcement schedule \( w_n \). For purely technical reasons, it is convenient to introduce an artificial control variable \( t(z) \), where \( t \) is a tax on the income of unpunished criminals. I do not allow \( t \) to be positive: \( t(z) \leq 0 \).

The individual chooses \( z, x_1, x_2, y, \) and \( p \) as described in equation 1. Equivalently, let the government choose the individual's control variables subject to the constraint that the choice satisfies the individual's necessary conditions given by the solution to equation 1. Furthermore, the punishment for no offense must be nil: \( 0 = f(0) = y(0) \).

In summary, the government's problem can be written

\[
\begin{align*}
\max_{v, x_1, x_2, y, p, w} & \sum_{n=1}^{N} [G(v_n) - v_n - p_n k y_n - c z_n + p f(z_n)] h_n d_n \\
\text{subject to} & \\
v &= \frac{\partial U}{\partial n} \quad (\text{See equation 4) } \quad \text{(C1)} \\
z &= z(v, p, x_1, x_2, y, n) \quad \text{(C2)} \\
x_1 &= A + z - t(z) \quad \text{(C3)} \\
x_2 &= A + z - f(z) \quad \text{(C4)} \\
y &= y(z) \quad \text{(C5)} \\
w &= w(p, n) \quad \text{(C6)} \\
x_2 &\geq 0 \quad \text{(C7)} \\
y &\geq 0 \quad \text{(C8)} \\
t(z) &\leq 0 \quad \text{(C9)} \\
0 &= f(0) = y(0). \quad \text{(C10)}
\end{align*}
\]
The first constraint is the differential equation for the state variable \( v \). Eliminate the second constraint by substituting everywhere for \( z \) and eliminating \( z \) as a control variable. The third constraint indicates that the government controls \( x_1 \) by choice of \( t(z) \). Eliminate the third constraint and the control \( t(z) \), substituting \( A+z-x_1 \) for \( t(z) \) in constraint 9. The fourth constraint indicates that the government controls \( x_2 \) by choice of \( f(z) \). Eliminate the fourth constraint and the control \( f(z) \). The fifth constraint indicates that the government controls \( y \) by choice of \( y(z) \). Eliminate the fifth constraint and the control \( y(z) \). Use the sixth constraint to substitute the function \( w(\cdot) \) for \( w \) everywhere, thus eliminating the control \( w \).

The tenth constraint requires that the punishment be nil for no offense: \( 0 = f(0) = y(0) \). The strategy for solving the problem is to convert this into a constraint upon the initial value of the state variable. Assume that the solution to the control problem exists. Let \( N_1 \) be the highest criminal wage along the optimal path at which \( z = 0 \). Let \( \bar{v}_{N_1} \) be the corresponding utility level. The tenth constraint is replaced by the initial condition \( v_{N_1} = \bar{v}_{N_1} \).

In its simplified form, the control problem is written:

\[
\max_{v_{x_1}x_2y} \int_{N_1}^{N_2} [G(v_{n}) - w(p,n) - p_n k y_n - cz(\cdot) + p(A+z(\cdot)-x_2)]h_n \, dn \\
\text{subject to} \quad \dot{v} = \frac{3U}{3n} \\
y \geq 0 \\
x_2 \geq 0 \\
A + z(\cdot)-x_1 \leq 0
\]
\[ v_{N_1} = \bar{v}_{N_1}. \]

The Hamiltonian can be written
\[
H = [G(v) - w(p, n) - pkv - cz(\cdot) + p(A + z(\cdot) - x_2)]h + \mu \frac{\partial U}{\partial n} + \lambda_1 y + \lambda_2 x_2
+ \lambda_3 (x_1 - A - z(\cdot)).
\]

The necessary conditions for a maximum are

I. \[ 0 = \frac{\partial H}{\partial x_1} = \frac{\partial H}{\partial x_2} = \frac{\partial H}{\partial y} = \frac{\partial H}{\partial p} \]

II. \[ -\dot{\mu} = \frac{\partial H}{\partial \nu} \]

III. \[ \dot{\nu} = \frac{\partial U}{\partial n} \]

IV. \[ v_{N_1} = \bar{v}_{N_1} \]

V. \[ 0 = v_{N_2} \]

VI. either \( \lambda_1 > 0 \) and \( y = 0 \), or \( \lambda_1 = 0 \) and \( y > 0 \)
    either \( \lambda_2 > 0 \) and \( x_2 = 0 \), or \( \lambda_2 = 0 \) and \( x_2 > 0 \)
    either \( \lambda_3 > 0 \) and \( x_1 = A + z \), or \( \lambda_3 = 0 \) and \( x_1 > A + z \).

The next task is to manipulate the necessary conditions in order to characterize the optimal punishment and enforcement schedules.

Pl. If \( ph(z_{x_2} - 1) > 0 \), then \( x_{2N_2} = 0 \), or in words, if increasing the fine does not diminish revenues from fines, then the most serious offender is fined the maximum amount which he can bear.

Proof:

From necessary condition I comes the equation
\[
0 = \frac{\partial H}{\partial x_2} = cz_x h + ph(z_{x_2} - 1) + \mu \frac{\partial U}{\partial x_2} + \lambda_2 - \lambda_3 x_2.
\]

At \( n = N_2 \), \( \mu = 0 \) by necessary condition V.
Either \( \lambda_2 > 0 \) or \( \lambda_2 = 0 \). Assume \( \lambda_2 = 0 \). Necessary condition I reduces to the expression

\[
0 = (-ch_3)z_{x_2} + ph(z_{x_2} - 1)
\]

which is a contradiction. Consequently \( \lambda_2 > 0 \), which implies \( x_2 = 0 \) by necessary condition VI.

\[
\star
\]

Obviously this proof applies even if imprisonment \( y \) is not a control variable, so the proof applies to crimes not punishable by incarceration.

P2. It is not the case that there exists an \( n \) where \( x_2 > 0 \) and \( y > 0 \), or in words, incarceration is not used except in conjunction with the maximum fine.

Proof:

Assume the contrary. From necessary condition I,

\[
0 = \frac{\partial H}{\partial x_2} = -cz_{x_2}h + ph(z_{x_2} - 1) + \mu \frac{\partial}{\partial x_2} \left[ \frac{\partial U}{\partial \bar{n}} \right] + \lambda_2 - \lambda_3 z_{x_2}
\]

\[
0 = \frac{\partial H}{\partial y} = (-pk-cz_y)h + phy + \mu \frac{\partial}{\partial y} \left[ \frac{\partial U}{\partial \bar{n}} \right] + \lambda_1 - \lambda_3 z_{y}.
\]

By assumption \( x_2 > 0 \) and \( y > 0 \), so it follows from necessary condition VI that \( 0 = \lambda_1 = \lambda_2 \).

Also, the symmetry of \( x_2 \) and \( y \) imply that

\[
\frac{\partial}{\partial x_2} \left[ \frac{\partial U}{\partial \bar{n}} \right] = -\frac{\partial}{\partial y} \left[ \frac{\partial U}{\partial \bar{n}} \right] \quad \text{and} \quad z_{x_2} = -z_y.
\]

Using these facts and adding the equations gives \( 0 = -pk - ph \), which is a contradiction.

\[
\star
\]
Obviously this proposition applies to each group of criminals when separated by their ability to pay $A$. Consequently, the worst offender in each class grouped by ability to pay will be charged the maximum fine which he is able to pay.

The next proposition concerns the optimal allocation of enforcement effort. Recall that the criminal's probability of punishment is a function $p = p(w(z), u)$. The following lemma is proved in footnote 11:

$$p_w = \frac{(1-z_{x_1}) - z_{x_2}(1-f'-y')}{z}$$

This lemma is derived from the criminal's first order conditions for utility maximization, assuming an interior solution.

P3. If $f' + y' > 1$, and $c > ph$, then $w' < 0$ at $n = N_2$, or in words, if the marginal punishment of the worst offender exceeds his marginal income from the offense, and if the harm done to victims exceeds the fine revenues from additional crime, then the optimal enforcement schedule has the property that the worst offender would face a higher probability of punishment if he committed a less serious offense.

Proof:
From necessary condition I,

$$0 = \frac{\delta H}{\delta x_1} = -cz_{x_1}h + phz_{x_1} + \lambda_3(1-z_{x_1}) + \mu_{x_1} \left[ \frac{\partial U}{\partial n} \right].$$

$\mu = 0$ at $n = N_2$ from necessary condition V. Consequently, the preceding equation reduces to

$$1-z_{x_1} = z_{x_1} \frac{h(c - h)}{\lambda_3}$$

which implies $(1-z_{x_1}) > 1$.  

This fact and the lemma imply that \( w' \) is negative:

\[
\frac{\frac{1}{p_w^2} - z_2 (1-f' - g')}{z_1 (1-z_2 - z_2)} < 0.
\]

\( p \) is an increasing function of \( w \), so by decreasing \( z \) the worst offender would increase the probability of punishment.

* 

Two of the three propositions which were proved concern the optimal schedule of punishments and probability for the worst offender, who is assumed to be the offender with the highest criminal wage \( N_2 \). Proofs are possible at the upper limit because the term \( \mu (\frac{\partial U}{\partial n}) \) drops out, due to the fact that \( \frac{\partial \mu}{\partial n} = N_2 \). At interior points this term does not drop out. It is possible to sign \( \mu \) and \( \dot{\mu} \).\(^{12/} \) It is also possible to sign \( \dot{\upsilon} \).\(^{13/} \) However, it is impossible to sign the derivative of \( \dot{\upsilon} \) with respect to the controls. This fact precludes general theorems about the interior values of the optimal path.

Example

Here is a simple numerical example of the discrete analogue to the control problem. Let \( f \) and \( i \) be parameters of the fine schedule and imprisonment schedules. Suppose the supply of crime for \( n \)-type offenders obeys the equation

\[ z_n = 1 - p_n - f - i. \]

Suppose that the cost of crime to its victims increases with the square of its seriousness: \( C = z^2 \). Suppose that the technology of enforcement
satisfies the equation $p_n = \min(1, \frac{4}{n} w_n)$, or equivalently, $w_n = \min(\frac{n}{4} p_1, \frac{n}{4})$.

Suppose that there are two criminals: $n = 1$ and $n = 2$.

The government tries to minimize the full cost of crime. If there are two criminals, $n = 1$ and $n = 2$, then the full cost of crime is

$$V = (z_1^2 + z_2^2) - (z_1 + z_2) + (1/4p_1 + 1/2p_2) + 4i^2.$$

harm to benefit enforcement jail
victims to cost cost
criminals

Assume that the constraint on the ability to pay a fine is given by $f \leq 1/8$.

Thus government solves

$$\min \ V \ \text{subject to } f \leq 1/8 \text{ and } z_n = 1 - p_n - f - i.$$

$$p_1 p_2 f_i$$

The derivative with respect to $f$ is

$$\frac{\partial V}{\partial f} = -\frac{3}{4}$$

$< 0$,

so at the optimum $f = 1/8$. Simultaneous solution of

$$0 = \frac{\partial V}{\partial i} = \frac{\partial V}{\partial p_1} = \frac{\partial V}{\partial p_2}$$

gives $i = 3/32$, $p_1 = 5/32$, and $p_2 = 1/32$.

Thus the maximum fine is used in conjunction with incarceration as predicted by P2, and the more serious offender is less likely to be punished than the less serious offender as predicted by P3.

This example can also be solved assuming that $i = 0$. In that case the optimal fine is maximal ($f = 1/8$), as predicted by P1. Furthermore, the more serious offender is less likely to be punished ($p_1 = 1/4$, $p_2 = 1/8$).
III. Control Formulation of Repeat Offenses

The model of repeat offenses is very close to the model of offenses ranked by seriousness. Let \( z \) denote the number of repetitions of a given offense by a criminal. Let \( p \) be the ratio of convictions to offenses. Consequently, \( pz \) will be the average number of convictions for \( z \) offenses. Retaining the notation used in Part II, the typical offender's utility from \( z \) offenses can be written

\[
U = u(-z/n, A+z-f(pz)-y(pz), n).
\]

The criminal chooses \( z \) to maximize \( U \). Thus the only change from Part II in the treatment of the individual criminal is that the model now proceeds in terms of the typical or average offender, with the stochastic variable eliminated. \( p \) is not interpreted as a probability, but as a ratio. Furthermore, the government does not choose a schedule \( p_n \), but instead chooses a single value \( p \).

The government's optimization problem is unchanged, except for the changes resulting from the different characterization of the individual criminal. The government solves

\[
\max_{v, x, y, p} \int \left[ G(v) - w(p) - ky - cz(\cdot) + p(A+z(\cdot)-x) \right] h \, dn
\]

subject to

\[
\begin{align*}
\dot{v} &= \frac{3U}{dn} \\
y &\geq 0 \\
x &\geq 0 \\
v &= \frac{V}{N_1}
\end{align*}
\]

The proofs of P1 and P2 go through without any change. These proofs
go through because the criminal's repetition of the crime depends upon the severity of the punishment which he faces, not whether the punishment is a fine or imprisonment. However, the proof of P3 is impossible in the revised model, because $p$ is now interpreted as a constant for all $n$, not a variable $p_n$. 
Comments on Mathematics

There are several features of the mathematical formulation which deserve comment. First, the reader should recognize that the proof of P2 (never incarcerate except in conjunction with the maximum fine) depends upon the assumption that imprisonment can be monetarized and added to the fine: \( u = u(-z/n, x-y, n) \). It would be desirable to find more general conditions under which the proof holds. However, the proof of P1 (the most serious offender is fined the maximum) does not depend upon these assumptions. The proof of P1 goes through unchanged if the utility function has the general form \( u = u(-z/n, x, y, n) \).

A second remark concerns the continuity assumptions. It seems possible that in practice the continuity assumptions are violated at the end points. At the lower end of the punishment schedule, there may be a discontinuity: \( 0 = f(0) \) and \( \lim_{z \to 0} f(z) = 0 \). In words, conviction for an infinitesimally small amount of crime may result in nonnegligible punishment. Similarly, at the upper end of the punishment schedule there may be a discontinuity, e.g. capital punishment. The model could be revised to take account of such discontinuities by a jump formulation. The characteristic outcome of such formulations is bunching of the densities at the end points.
IV. Interpretation and Limits

The propositions developed graphically in Part I and mathematically in Parts II and III assume that criminals are rational and the objective of punishment is to minimize the full cost of crime. This section probes the interpretation and limits of those assumptions. The aim is to make good my assertion in the introduction that the proofs are robust with respect to many changes in the assumptions.

Utility and Efficiency

Bentham's vision of an exact jurisprudence included the precise calibration of punishments. The aim was to construct a schedule of punishments which would maximize the sum of the utilities of everyone in society. What is the relationship between maximizing utility and minimizing the cost of crime? Is the model in this paper a version of utilitarianism?

The difference between minimizing costs and maximizing utility comes down to a difference in the weight given to the income of different classes in society. Cost minimization is equivalent to maximization of national income or wealth. National income is the unweighted sum of individual incomes. The total income or wealth is unaffected by its distribution.

By contrast, the utilitarian tradition in economics stresses the goal of maximizing welfare. The welfare of a nation depends upon the amount of its income or wealth and the distribution of it. The utilitarian tradition stresses that poor people get more welfare or utility from additional income than rich people, because the poor use it to satisfy basic human needs. According to this tradition, the welfare of the nation goes up if income is distributed more equally, even if total income is unchanged. The difference between the two approaches comes down to
whether the income of the poor is given the same or more weight than the income of the rich in determining policies.

The presentation in Part I of the paper stressed cost minimization, i.e. maximizing national income, but the theorems which were proved in Parts II-III are true regardless of the weight given to the income of different classes of people. It does not matter whether the income of the poor is given more or less weight than the income of the rich.17/ Thus the theorems are true whether the objective of punishment is utility or efficiency. The model in this paper is consistent with a utilitarian approach, but it is also consistent with a narrower efficiency approach.

Limits of Utility

The weaknesses of utilitarian theories of punishment are well known to philosophers.18/ The model in this paper can be given a utilitarian interpretation. Is the model in this paper vulnerable to those criticisms?

The most fundamental criticism of utilitarian theories of punishment is that they establish a weak link between punishment and guilt. For purposes of deterrence it is enough that people believe that offenders will be punished and innocent people will not be punished. It is possible to think of ways to strengthen this belief by violating the rights of individuals. Why not frame an innocent person and punish him to deter others? Why not falsify evidence to secure a conviction if there is no chance of the falsification being discovered? Why not frighten potential murderers by televising executions? A case could be made that each of these devices would reduce the full cost of crime.

Retributivism is the leading alternative to utilitarianism.19/
Retributivists hold that a person should be punished because he broke the law, not because punishing him will minimize the full cost of crime. The strength of retributivism is the strong link it establishes between guilt and punishment.

If I grant that guilt is the only reason which justifies punishment, then I still need to know how much to punish. A standard for calibrating punishment is required. Retributivists often try to solve this problem by making the punishment fit the crime, e.g. an eye for an eye, a tooth for a tooth, etc. The standard is that the severity of the punishment should be proportional to the seriousness of the crime. This standard protects the criminal against excessive punishment, even in circumstances where harsh punishments reduce the full cost of crime.²⁰/

Whatever its philosophical merits or deficiencies, the proportionality standard is vague compared to the cost minimization standard. The cost minimization approach is more likely to yield precise answers for a complex society with many different laws. However, the retributivist theory establishes a strong link between guilt and punishment, thus protecting individual rights better than the cost minimization approach. Is it possible to combine these theories and get the best of both?

It is straightforward to combine these theories by treating retributivism as a set of constraints upon the minimization of the full cost of crime. Cost minimization can be constrained by the requirement that innocent persons should not be punished. Mathematically, this constraint is the requirement in my model that the punishment should be nil for no offense. Cost minimization can also be constrained by the requirement that punishment not be excessive. Mathematically, this constraint is the
requirement that the punishment schedule not exceed certain levels for each offense.

It is easy to illustrate the constraint against excessive punishment by my treatment of fines. In the presentation of the model I stated that the fine cannot exceed the offender's ability to pay, i.e. the fine cannot exceed the offender's wealth or income. However, the ability to pay could be given a moral or legal interpretation, i.e. the fine cannot exceed the amount specified by the proportionality doctrine. This change in interpretation would make no difference to the theorems.

This discussion illustrates how to combine utilitarian and retributivists elements into a unified approach. From a philosophical viewpoint, the strategy is to pursue a social goal which is utilitarian in character (cost minimization), without violating individual rights which are not utilitarian in character. From a mathematical standpoint, the strategy is to maximize a utilitarian objective function subject to retributivist constraints.

Progressivity of Punishments

Should a rich person be fined more than a poor person who commits the same offense? Should a poor person with no ability to pay a fine be jailed for an offense that would be punished by a fine for a rich offender?
These questions could be answered by direct appeal to a moral theory or moral intuition, and then the answer could be imposed as a constraint upon the problem of minimizing the full cost of crime. I leave to the others the problem of exploring the moral issues. Instead I shall sketch the answer that comes from solving the cost minimization problem without moral constraints.

The most important theorem in the model states that incarceration should not be used until the ability to deter by fines has been exhausted. The ability to deter by fines is different according to the wealth or income of the offender. Consequently, the full cost of crime will not be minimized unless the schedule of fines adjusts to the offender's wealth. Cases would arise in which a rich person was fined more than a poor person who committed the same offense, and a rich person was fined for the same offense that resulted in jailing a poor person. 21/

This conclusion contradicts an argument in Becker's classic article on the economic analysis of crime. Becker argued that an efficient system of fines would base the fine on the harm caused by the offense, not the ability of the offender to pay. 22/

Becker's line of reasoning can be appreciated by appeal to the familiar prescriptions of economists with regard to pollution. The economic problem of pollution is that the polluter does not bear the cost of the harm which he imposes upon others. In other words, the cost of pollution is externalized. If the polluter is made to pay a tax equal to the harm caused by his pollution, then the cost of pollution will be internalized. Internalization of the cost of pollution will result in an efficient amount of pollution.
The criminal is like the pollutor in the sense that he does not bear the cost of the harm which he imposes upon others. Efficiency can be achieved by internalizing the harm caused by crime. If enforcement is costless so that crime is always punished, then internalization is achieved by setting the fine exactly equal to the harm. If enforcement is costly, then internalization requires the offender to bear the cost of the harm to others and the enforcement costs. In either case, the fine depends upon the harm done to others, not the offender's ability to pay. This is Becker's argument in a nutshell.

This argument applies to a world in which all offenders are able to pay for the harm caused by their acts. The model in this paper envisions a different world, whose characteristic is that the harm done by the worst offenders exceed their ability to pay fines. This is a second best world in which complete internalization of the cost of crime is impossible.

In a second best world, imposing a fine uses up a scarce resource, namely the ability to deter cheaply. If the fine for mild offenses is increased, then the ability to deter serious crimes by fines will be diminished. To see this point, suppose that an offender is able to pay at most a fine of $10,000, and suppose that he commits an offense which causes $10,000 worth of harm. If the offender faces a fine of $10,000, then he cannot be deterred by fines from committing a more serious offense or repeating this offense. It might be desirable to fine him less than $10,000 for this offense in order to preserve a cheap deterrent against more serious offenses or repeat offenses.
The opportunity cost of fines is positive if fines are "scarce." Fines are scarce if the harm done by the worst offender exceeds his ability to pay a fine, i.e. if full internalization is impossible. If internalization is impossible for serious offenders, then internalization may be undesirable for mild offenders. (This is an application of the second best theorem.) Specifically, the optimal fine for mild offenders may be less than the harm which they cause, thus preserving a high marginal fine for serious offenders.

Our major conclusion is that optimal fines depend upon both the severity of the offense and the ability of the offender to pay. The system of fines adopted in many European countries has this characteristic. The Swedish system of day fines will be described briefly in Part V.

Rationality of Criminals

In my model the criminal decides how serious an offense to commit or how many times to repeat the same offense. The mathematical treatment of this decision involves complicated computations. These computations are in the economist's mind, not the criminal's mind. The model requires that criminals respond to risk. Specifically, it requires that they reduce crime in response to an increase in the probability or magnitude of punishment. The model does not require that criminals base their response on elaborate computations. The intelligence of a laboratory rat will
probably suffice.23/

The limited econometric evidence supports the conclusion that criminals respond to risk.24/ The dispute concerns how much they respond. In economic jargon, the dispute concerns the magnitude, not the signs of the elasticity of the supply of crime. Fortunately, this dispute does not impinge upon the conclusions of my model. The theorems proved in Parts I-III are true regardless of the magnitudes of the elasticities, provided that the signs are right.

There is an important defect in my account of repeat offenses which could impugn its conclusions. The defect does not touch upon the rationality of offenders. Rather it touches upon the omission of time from the model. In my model criminals drop out of the pool of offenders because the punishment increases for repeat offenses. The criminal drops out when he perceives the risk to be greater than the gain. The criminal's evaluation of risk in my model is unaffected by his age.

Criminologists believe that age is an independent determinant of the propensity to commit crime.25/ If this belief is accurate, then criminals may evaluate risk differently as they grow older. An offender may change his mind and perceive the gain from crime as not worth the risk just because he has grown older, not because the punishment has increased.

In my model offenders stop repeating because the punishment becomes too severe relative to the gain. Replacing one form of punishment by another of equivalent severity does not influence the total number of crimes. I concluded that replacing imprisonment by equivalent fines will not
effect the total amount of crime, although it will cause repeat offenders to drop out at an earlier age. This conclusion is vitiated if age is an important independent determinant of crime. If younger criminals are less averse to risk, then greater risk will be required to cause an offender to drop out when he is young than when he is old. If age is important, then incapacitating criminals during youth, rather than imposing fines of equivalent deterrence value, will reduce the total amount of crime.

The effects of age and the increasing severity of punishment on repeat offenses are difficult to untangle in empirical studies. No conclusive answer is possible at this time, but I suspect that replacing incarceration with equivalent fines would have little effect upon the total amount of crime.
V. Policy

The main policy conclusion from the theorems is that imprisonment should not be used as a punishment until the offender's ability to pay a fine is exhausted. Comparing this conclusion to the actual practice of U.S. courts requires extensive data. It is necessary to determine the extent to which offenders are jailed who could be deterred by fines. Such an assessment requires data on the use of fines and the ability of offenders to pay them. Much of the needed information has not been collected, but it is possible to form an impression of current practices from existing data.

Tables 1 and 2 describe the use of fines in California courts and federal courts. The outstanding difference is that California uses fines more extensively for comparable offenses, as can be seen by comparing column 6 in the two tables. The other outstanding feature is that jail or imprisonment is seldom combined with a fine, contrary to the proposition about optimal sentencing derived in this paper.
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<thead>
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<tbody>
<tr>
<td>1. Homicide</td>
<td>---</td>
<td>0.20%</td>
<td>0.50%</td>
<td>0%</td>
<td>0%</td>
<td>0.70%</td>
<td>0.35%</td>
<td>2.80%</td>
<td>0.20%</td>
<td>96.00%</td>
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<tr>
<td>2. Rape</td>
<td>---</td>
<td>0.15%</td>
<td>3.30%</td>
<td>0%</td>
<td>0.16%</td>
<td>3.62%</td>
<td>0.80%</td>
<td>15.70%</td>
<td>0.30%</td>
<td>79.00%</td>
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<tr>
<td>3. Robbery</td>
<td>---</td>
<td>0.60%</td>
<td>3.70%</td>
<td>0%</td>
<td>0%</td>
<td>4.30%</td>
<td>1.5%</td>
<td>23.00%</td>
<td>0.20%</td>
<td>71.00%</td>
<td>301</td>
</tr>
<tr>
<td>4. Burglary</td>
<td>---</td>
<td>5.50%</td>
<td>14.60%</td>
<td>0.30%</td>
<td>0.40%</td>
<td>20.8%</td>
<td>4.60%</td>
<td>44.00%</td>
<td>8.20%</td>
<td>22.30%</td>
<td>13,057</td>
</tr>
<tr>
<td>5. Auto Theft</td>
<td>---</td>
<td>10.00%</td>
<td>24.00%</td>
<td>0%</td>
<td>0%</td>
<td>34.00%</td>
<td>5.70%</td>
<td>39.00%</td>
<td>12.00%</td>
<td>28.00%</td>
<td>210</td>
</tr>
<tr>
<td>6. Battery</td>
<td>---</td>
<td>20.00%</td>
<td>15.00%</td>
<td>0.90%</td>
<td>3.60%</td>
<td>39.50%</td>
<td>11.40%</td>
<td>34.00%</td>
<td>15.00%</td>
<td>0.10%</td>
<td>2,566</td>
</tr>
<tr>
<td>7. Embezzlement</td>
<td>---</td>
<td>29.00%</td>
<td>15.00%</td>
<td>0.80%</td>
<td>3.10%</td>
<td>47.90%</td>
<td>9.30%</td>
<td>30.00%</td>
<td>11.00%</td>
<td>1.80%</td>
<td>480</td>
</tr>
<tr>
<td>8. Fraud</td>
<td>---</td>
<td>34.20%</td>
<td>22.50%</td>
<td>0.40%</td>
<td>1.70%</td>
<td>58.80%</td>
<td>15.30%</td>
<td>20.20%</td>
<td>4.40%</td>
<td>1.20%</td>
<td>1,652</td>
</tr>
<tr>
<td>9. Traffic Violations</td>
<td>---</td>
<td>11.00%</td>
<td>5.80%</td>
<td>3.80%</td>
<td>51.00%</td>
<td>71.60%</td>
<td>3.00%</td>
<td>6.30%</td>
<td>16.00%</td>
<td>3.00%</td>
<td>735</td>
</tr>
<tr>
<td>10. Reckless Driving</td>
<td>---</td>
<td>51.00%</td>
<td>13.00%</td>
<td>1.30%</td>
<td>20.00%</td>
<td>85.30%</td>
<td>3.30%</td>
<td>6.00%</td>
<td>5.00%</td>
<td>0%</td>
<td>1,206</td>
</tr>
</tbody>
</table>

Sources
State of California, Bureau of Criminal Statistics and Special Services, Adult Felony Arrest Dispositions in California (1980), Table 10, p. 41.
### Table 2. USE OF FINES BY FEDERAL DISTRICT COURTS IN 1980
PERCENTAGE DISTRIBUTION OF CONVICTED OFFENDERS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Homicide</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>---</td>
<td>0%</td>
<td>0%</td>
<td>15.00%</td>
<td>7.40%</td>
<td>76.50%</td>
<td>1.0%</td>
<td>94</td>
</tr>
<tr>
<td>2. Rape</td>
<td>3.30%</td>
<td>0%</td>
<td>0%</td>
<td>---</td>
<td>0%</td>
<td>3.30%</td>
<td>30.00%</td>
<td>3.30%</td>
<td>60.00%</td>
<td>3.30%</td>
<td>30</td>
</tr>
<tr>
<td>3. Robbery</td>
<td>0.80%</td>
<td>0.40%</td>
<td>0%</td>
<td>---</td>
<td>0%</td>
<td>1.20%</td>
<td>6.20%</td>
<td>3.70%</td>
<td>88.70%</td>
<td>0.08%</td>
<td>1208</td>
</tr>
<tr>
<td>4. Burglary</td>
<td>0.60%</td>
<td>0.60%</td>
<td>0%</td>
<td>---</td>
<td>0%</td>
<td>1.20%</td>
<td>10.00%</td>
<td>7.00%</td>
<td>81.70%</td>
<td>0%</td>
<td>794</td>
</tr>
<tr>
<td>5. Embezzlement</td>
<td>1.60%</td>
<td>17.40%</td>
<td>1.60%</td>
<td>---</td>
<td>10.50%</td>
<td>31.10%</td>
<td>43.00%</td>
<td>12.00%</td>
<td>1.60%</td>
<td>0.40%</td>
<td>2719</td>
</tr>
<tr>
<td>6. Fraud, general</td>
<td>4.00%</td>
<td>15.00%</td>
<td>4.00%</td>
<td>---</td>
<td>3.60%</td>
<td>26.60%</td>
<td>36.50%</td>
<td>16.70%</td>
<td>19.30%</td>
<td>0.50%</td>
<td>2105</td>
</tr>
<tr>
<td>7. Fraud, income tax</td>
<td>7.40%</td>
<td>39.00%</td>
<td>15.70%</td>
<td>---</td>
<td>4.10%</td>
<td>62.60%</td>
<td>13.50%</td>
<td>12.00%</td>
<td>7.80%</td>
<td>0.10%</td>
<td>699</td>
</tr>
<tr>
<td>8. Auto Theft</td>
<td>1.60%</td>
<td>7.00%</td>
<td>0.70%</td>
<td>---</td>
<td>0.40%</td>
<td>9.70%</td>
<td>16.70%</td>
<td>14.00%</td>
<td>59.00%</td>
<td>0.40%</td>
<td>417</td>
</tr>
</tbody>
</table>

**Sources**

It is difficult to obtain an indication of the ability to pay fines on the part of convicted criminals, because not much data has been collected on the income of offenders. The U.S. Department of Justice surveyed inmates in local jails in 1978 and asked them to report various facts, including their income. 26/45 percent of respondents reported working full time and 43 percent reported dependents. 38 percent reported annual personal income of less than $3,000, while 10 percent reported income over $10,000. 19 percent reported schooling less than 9 years of schooling, and 10 percent reported some college.

The picture that emerges from the data on the ability of inmates in local jail to pay fines suggests that at least half have some ability to pay. The proportion may be higher, since inmates in local jails may be poorer than convicted offenders on average. The bias arises because jail inmates include those awaiting trial who cannot make bail, as well as those who have been convicted. When these observations are combined with the high proportion of sentences involving jail but no fine, it seems likely that there is scope for substituting fines for incarceration.

This conviction is strengthened by the observation that some states make greater use of fines than others. It is reported that 29 percent of the sentences were fine only in Pennsylvania's major criminal courts in 1967. 26 percent of the felony sentences in Pennsylvania in 1949 were "fine only." The wider use of fines in that state is possible because a fine can be imposed under state law for all crimes except first degree murder. 27/
In Europe the process of substituting fines for imprisonment has proceeded much farther than in the United States. Fines were 95 percent of all sentences imposed in Sweden by 1953 and in Finland by 1959. In part the greater reliance upon fines reflects higher employment levels and greater ability to pay. However, the trend is also a result of changes in the law to extend the scope of fines.

A brief description of the Swedish system explains how to extend fines as an instrument of punishment. In Sweden the unit for denoting fines is the "day fine," which equals .1 percent of the offender's annual income. The penalty meted out to the offender is specified in terms of day fines. Deductions are possible for dependents and corrections for unusual wealth (as opposed to income) are also made. The payments may be made in installments. In the event that the offender fails to pay the fine, he may be sentenced to one day in jail for each day fine outstanding. In brief the Swedish system bases fines upon the seriousness of the offense and the offender's ability to pay, with adjustments similar to the income tax. (The adjustments could already be included in the specification of the day fine if it equalled .1 percent of the offender's taxable annual income.) Collecting the information necessary to administer this system has apparently proved to be inexpensive.

In 1978 federal, state, and local governments spent $5.5 billion on corrections. This figure is almost half the public expenditure on police protection and ten times the expenditure on public defense. The cost to the state of keeping a person in prison for one year is large by every estimate. Contemporary computations for California prisons indicate that annual maintenance cost per prisoner varies from $12,000 to over $20,000, depending upon the prison, with construction costs per cell exceeding $50,000. Substituting fines for imprisonment could result in large savings to the government.
There are some legal obstacles in America to imprisonment for non-payment of fines. The Supreme Court held that indigent offenders could not be jailed for nonpayment of fines, but must be given an opportunity to pay in installments. The California Supreme Court absolutely prohibited imprisonment of indigents for nonpayment of fines. Legislation in Delaware prohibits imprisonment of anyone, indigent or wealthy, for nonpayment of fines. However, it seems likely that many court objections, which are based upon equal protection, would be removed if fines were calibrated by ability to pay and payment in installments were possible.

Discovering the rate of which fines can be substituted for imprisonment without loss of deterrence is difficult. Some evidence has been collected concerning subjective judgments of the severity of punishments. Sebba asked college students to rate penalties by severity. As an example of the results, in 1978 Temple students considered a fine of $50,000 to be worse than 10 years in prison, but not as bad as 15 years. A fine of $500 was rated as more severe than one year's probation and less severe than 6 months imprisonment. Computing substitution rates is obviously difficult, but it may be no more difficult than other fundamental calculations about the effects of punishments, such as determining the deterrence effects of incarceration.

Probabilities

The model predicted that the optimal allocation of enforcement effort might result in a lower probability of punishment for more serious offenses. Table 3 shows the probability of punishment for various offenses ranked by seriousness. The crude data does not confirm the prediction. In fact, the probability of punishment increases with the seriousness of the offense.


Table 3: Punishment Probabilities

<table>
<thead>
<tr>
<th>Crime</th>
<th>Unadjusted Probability</th>
<th>Adjusted Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>homicide</td>
<td>.76</td>
<td>.76</td>
</tr>
<tr>
<td>rape</td>
<td>.50</td>
<td>.14</td>
</tr>
<tr>
<td>robbery</td>
<td>.26</td>
<td>.13</td>
</tr>
<tr>
<td>burglary</td>
<td>.16</td>
<td>.06</td>
</tr>
<tr>
<td>auto theft</td>
<td>.15</td>
<td>.10</td>
</tr>
</tbody>
</table>

Notes

a. Clearance rates.

b. Clearance rates adjusted for underreporting by using victimization studies.

Sources

One possible reason for this result is that serious offenses are committed by repeat offenders, and repeat offenders are easier to apprehend. It would be desirable to amend the data to show the punishment probability for first offenses. Another problem concerns the fact that some crimes by their nature yield evidence required for convictions, e.g. homicide produces a body. The predicted effect of decreasing probabilities might only be present for crimes in which the more serious offenses are not intrinsically easier to solve. The proposition that punishment probability diminishes with the seriousness of the offense remains a conjecture.
Conclusion

If criminals respond rationally to risk and if minimizing the full cost of crime is desirable, then control theory as developed by economists can be used to reach three conclusions about the optimal punishment schedule. First, imprisonment should not be used except in conjunction with the maximum fine. Second, if imprisonment is excluded as a punishment for the class of offenses being considered, then the fine for the worst possible offense should be the maximum fine which the offender can bear.

These two conclusions are robust with respect to many changes in mathematical or philosophical assumptions. For example, elements of a retributivist theory of punishment can be introduced without changing the conclusion. Furthermore, the conclusions are true when applied to "career criminals" who repeat their offenses.

The third conclusion is that the optimal probability of punishment decreases with the seriousness of the offense at the upper end of the scale of offenses. This conclusion is not so robust and may be an artifact of the particular mathematical model.

A casual examination of the data suggests that there may be scope for substituting fines for imprisonment in the United States. An optimal system would utilize day fines based upon the seriousness of the offense, the number of offenses, and the offender's ability to pay. Replacing imprisonment with fines could save government a lot of money and there may be many intangible benefits from keeping offenders out of jail which are not captured in the economic model.
Footnotes

1. This is the so-called "Ramsey commodity tax problem." For example, see A. B. Atkinson and Joseph Stiglitz, Lectures on Public Economics (1980), lecture 12.


4. A recent formulation and proof of this proposition, along with complete references to the origins of the proposition, is in A. Mitchell Polinsky and Steven Shavell, "The Optimal Tradeoff Between the Probability and Magnitude of Fines," AER, Dec. 1979, vol. 69, pp. 880–891.

5. A more exact discussion of this transformation is in Part II, especially at footnote 8.

6. The assumption is that n is distributed uniformly.

7. In many states the parole board has formal tables in which the recommended time to be served depends upon the severity of the offense and previous offenses. For example, see Administrative Rules of Oregon State Board of Parole (mimeo, Feb. 1979).

8. A sufficient condition for the existence of a transformation from time in prison to dollars with the properties described in this model is additive separability of u. To see this point, write the general utility function

\[ u = u(-z/n, x, y, n). \]

Assume that it is additively separable:

\[ u = u_1(-z/n) + u_2(x) + u_3(y) + u_4(n). \]

Transform the utility function into units of dollars rather than utils:

\[ \phi(u) = \phi(u_1(\cdot)) + x + \phi(u_3(y)) + \phi_4(n). \]

The function \( \phi(u_3(\cdot)) \) transforms time in prison into dollar equivalents.
9. See citations in footnote 2.

10. In the efficiency approach, $G(\cdot)$ is derived as follows: Let CME represent the certain monetary equivalent of the gamble, so that

$$u(z/n, \text{CME}, n) = v.$$ 

Choose an arbitrary value of $z$ in $u(\cdot)$, and invert:

$$\text{CME} = u^{-1}(v, -z/n).$$

The function $u^{-1}$ is $G$ as defined by the efficiency standard.

11. Write the individual's maximization problem as follows:

$$\max_{x_1, x_2, y} \quad U = (1-p)u(-z/n, x_1, n) + pu(-z/n, x_2-y, n)$$

$$+ \alpha(p-p(w(z), n))$$

$$+ \beta(A+z-x_1)$$

$$+ \sigma(-f(z)+A+z-x_2)$$

$$+ \delta(y-y(z)).$$

Find the first order conditions and take ratios to obtain $\frac{dp}{dz}$, $\frac{dp}{dx_1}$, $\frac{dp}{dx_2}$, and $\frac{dp}{dy}$. By combining these equations, the desired equation is obtained.

12. Necessary condition II is written

$$-\dot{\mu} = \frac{3H}{\delta v} = W' + cz_v + pz_v + \mu \frac{\delta U}{\delta n} - \lambda z_v$$

$$= [W' + z_v (-c\lambda + \phi)] + \left[ \frac{3}{\delta v} \left( \frac{\delta U}{\delta n} \right) \right] \mu.$$ 

Define $a(n)$ and $b(n)$ to equal the terms in square brackets and solve the differential equation:

$$-\mu = [a(n)] + [b(n)]\mu$$

$$\Rightarrow -\mu = \int^2 a(m) \exp\left[ \int b(\tilde{m}) d\tilde{m} \right] dm - K.$$ 

The exponential function is nonnegative. If $c>1$, then the sign of $a(\mu)$ is positive:

$$a(m) = W' + z_v (-c\lambda + \phi) > 0.$$
Furthermore, $\mu_2 = 0$. So we have $\mu \leq 0$ and $\mu \geq 0$.

13. Write necessary condition III and expand it according to equation 4:

$$\hat{V} = \frac{3U}{\hat{n}}$$

$$= \left[ u(-z/n, x_2, y, n) - u(-z/n, x_1, n) \right] (-\omega_2/\omega_1)$$

$$+ \frac{1}{\omega_1} + [(1-p)u_1(-z/n, x_1, n) + pu_1(-z/n, x_2, y, n)]z/n^2.$$  

If $w_2 < 0$, i.e. if criminals with higher criminal wages are not intrinsically easier to catch and convict, then $\hat{V} > 0$.

13b. See Kenneth Arrow and Mordecai Kurz, *Public Investment, the Rate of Return, and Optimal Fiscal Policy* (1970), 51.


15. The utilitarian tradition in economics is discussed in Robert Cooter and Peter Rappaport, "Were the Cardinalists Right After All?" (mimeo, fall 1981).

16. This position is taken by Pigou in his classic, *The Economics of Welfare*.

17. In the objective function of the control problem, $W(v)$ must be increasing, $W' > 0$, but the rate of increase is inconsequential to the theorems.


20. See Hart, op. cit. at n.19.

21. The control problem assumed that legitimate income or wealth $A$ was the same for everyone. Hence the optimum must be interpreted as a statement about a group of offenders who are all in the same income class.


The possibility that the optimal fine is less than the harm is discussed in Polinsky, "Private Versus Public Enforcement of Fines," *J. Legal Stud.*, 105 (1980).

23. The "laws" of economics have been confirmed in animal studies. For example, see


37. For an account of the perils of determining probabilities from police data, see Richard Block and Carolyn Block, Criminology Decisions and Data: The Transformation of Robbery Incidents into Official Robbery Statistics, 71 J. Criminal Law & Criminology 622 (1980).