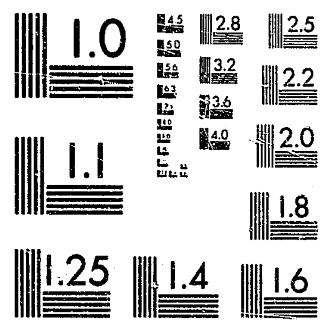

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The Urban Public Sector and Urban Crime: A Simultaneous System Approach

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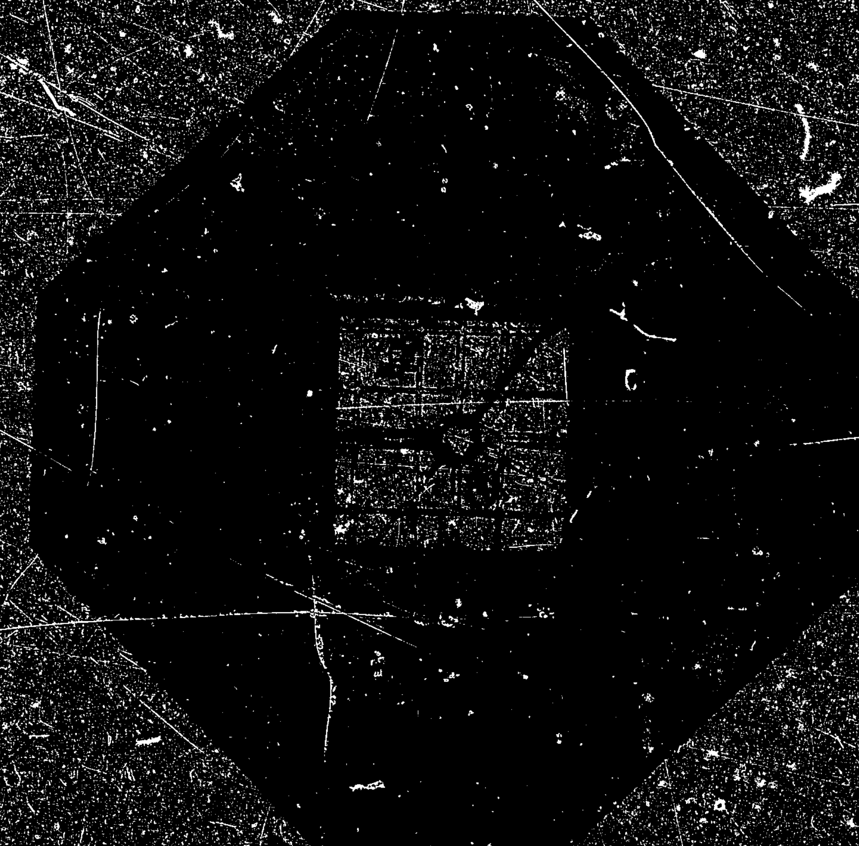

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The Urban Public Sector and Urban Crime:
A Simultaneous System Approach

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Joel L. Naroff

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ABSTRACT

"The Urban Public Sector and Urban Crime: A Simultaneous System Approach"

This study is an effort to describe the complex interactions between the urban public sector and urban crime. To develop the model, prototypes of previous modelling efforts are reviewed in detail and critiqued for theoretical foundation, empirical content and methodology, and policy relevance. Based on the review, theoretical and methodological requisites for a complete model are defined.

A simultaneous equation model is then developed which incorporates the impact of crime on property values and tax revenues, the impact of both revenues and crime on local law enforcement expenditures, and the relationship between public criminal justice expenditures and criminal activity. Intergovernmental and inter-agency impacts within the criminal justice system are recognized. The simultaneous approach stresses the systematic aspects of the interplay of criminal justice agencies in urban settings and highlights the role of agency cooperation.

The econometric model described is a system of five equations: a supply of criminal offenses function; a law enforcement production function; a police services demand function; a city revenue function; and, a city property value function.

The usefulness of the model for public policy analysis is demonstrated. Policy "multipliers" and methodological issues and data requirements for empirical estimation of the model are presented in appendices.

EXECUTIVE SUMMARY

"The Urban Public Sector and Urban Crime: A Simultaneous System Approach"

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ACKNOWLEDGEMENTS

We are grateful to the National Institute of Justice for providing us with this opportunity to explore a topic of interest to us personally, and of general importance to those concerned with the equitable and efficient delivery of criminal justice in urban areas. We hope that we have made some contribution to the understanding of the issues and problems involved, as well as the potential solutions.

We wish to acknowledge the assistance of our project monitor, Dr. Bernard Gropper, and the helpful suggestions of several anonymous reviewers. Cheryl Noakes and Pauline Sayers provided first rate typing assistance.

EXECUTIVE SUMMARY

This study is an effort to describe the complex interactions between the urban public sector and urban crime. The impact of relatively high crime rates on urban property values, and the resultant interaction with the public sector has not previously been systematically examined, either theoretically or empirically. Yet an examination of this impact is a necessary part of our analysis of urban problems, as well as our development of a comprehensive attack against urban crime, for the ability of the urban public sector to respond to the crime problem in part depends on the resources available to it, more specifically, its tax base. Since the property tax continues to be the prime source of revenue at the local level, even in the largest cities, aggregate urban property values affect the ability of urban centers to maintain law and order within their boundaries. It is the interrelationship between urban crime and the ability of the urban public sector to fight crime which is the focus of this study.

Our purpose is to describe, or model the interactions in terms of a system of simultaneous equations. While methodologically necessary, the simultaneous approach has the advantage of stressing the systematic aspects of the interplay of criminal justice agencies in urban settings. Thus, by recognizing both intergovernmental and inter-agency behavioral impacts in a series of interdependent equations, the model highlights the role and importance of agency cooperation within the system.

To develop the model, our method has been to review prototypes of previous model building efforts and to critique each in terms of its theoretical foundation, empirical content and methodology, and public policy relevance. Thus we present a detailed review and summary of various efforts to describe aspects of the urban crime/urban public sector interactions.

The central hypothesis of our model is that crime rates affect urban property values. These, in turn, affect urban public revenues, primarily those derived from the property tax, but also any intergovernmental transfers distributed according to tax base. Crime rates may also affect revenues through an impact on conditional transfers distributed specifically for law enforcement. Urban public revenues determine the city budget, including that for police and other local criminal justice expenditures. These expenditures at the local level, as well as expenditures elsewhere both public and private, are likely to affect urban crime rates. They are also likely to be affected by crime rates; thus the crime rate may be a function of the criminal justice budget, but the criminal justice budget may also be a function of the crime rate.

We present a comprehensive model of these interactions between the urban public sector and urban crime. Information from the model can be used in a variety of ways to facilitate development and evaluation of policies directed toward urban crime control. Criminal justice system constraints imposed by other levels of government which affect the urban system can be identified and the additional policy implications addressed. The role and importance of public sector agency cooperation can be identified.

Section I. IDENTIFICATION AND CRITIQUE OF RELEVANT MODELS

In the first section of the study a detailed review and description of fourteen previous related model building efforts is presented. These models cover roughly a ten year period, beginning in 1968 with a paper by Gary Becker. Each model is examined and critiqued in terms of both theoretical and

technical qualities as well as policy relevance. With the exception of the first three models reviewed, each model contains empirical work. This discussion of the models is arranged in chronological order, which roughly parallels the conceptual development and permits historical comparison. In reviewing each study its contribution to the development and empirical estimation of models of the relationships among crime, law enforcement efforts, and public revenues is focused upon. Some studies examine only part of this picture, while others are more comprehensive. Still others accomplish a great deal more than modelling these relationships and focus on other aspects of the economics of crime. In such cases, the review is restricted to that portion relevant to the central purpose of the study. This is not to suggest that the additional contributions of those papers are not important. The survey includes simultaneous systems models, single equation models, and verbal models.

Section II. SUMMARY AND DEVELOPMENT OF PREVIOUS MODELS

Based on the review of prototypes of previous model building efforts, a variety of theoretical and empirical developments are identified in Section II and the need to incorporate the perspective of some of the models, as well as to add dimensions which have been largely ignored is determined. Specifically, an adequate policy-relevant model of crime, law enforcement and the public sector requires several elements, some of which are present, in part, in previous models, some of which have not been included. The requisities identified in Section II are:

1. Specification of a simultaneous equation system which can describe the simultaneous nature of the interaction, not only between crime and law enforcement activities, but also among crime, property values, public revenues, and public expenditures, or police budgets.

2. Use of local government as the appropriate focus of the model and, therefore, as the data base for empirical work.
3. Recognition of the impact of tax base, tax effort, and intergovernmental transfer payments on the revenues available to local government.
4. Recognition of the interactions among various elements of the criminal justice system -- the police, courts and corrections -- and the constraints imposed by one system, or level of government, on the expenditures and outputs of the local government sector, including local police. Such recognition would highlight the role and importance of agency/jurisdictional cooperation within the criminal justice system.
5. Consideration of the impact of other urban characteristics, such as economic well-being and housing quality, on the level of criminal activity in urban areas, and recognition of the potential of these for development of alternative policy for controlling crime. This, in combination with 4), further highlights the role of complementary and cooperative public policy efforts.

In addition to the theoretical structure requirements of the model, there are some methodological requirements:

1. Recognition of the possibility of lagged responses of some variables to "causal" factors via introduction of distributed lagged functions.
2. Use of adequate statistical techniques designed for estimation of simultaneous systems of equations.
3. Appropriate specification of functions within the system so that each function is properly identified and the impact of each variable within the system can be clearly determined.
4. Inclusion in the analysis of a potentially large number of urban characteristics which are likely to be highly correlated, by using an appropriate data reduction technique, such as principal components analysis or ridge regression.

Section III. A SIMULTANEOUS EQUATION MODEL

With these requirements in mind, a model which meets, or is capable of meeting both the theoretical and methodological requisites outlined is described. The third section of the study presents an illustrative model which includes the important aspects of the interaction between the urban public sector and urban crime. In the model various impacts are recognized:

1. The impact of crime on property values and tax base.
2. The impact of tax base, tax effort and intergovernmental transfers on local tax revenues.
3. The impact of both crime and local fiscal constraints on law enforcement expenditures.
4. The impact of criminal justice expenditures on law enforcement productivity.
5. The impact of law enforcement activity, as well as other variables, on crime.

Interactions among components of the criminal justice system, and among levels of government are recognized. The model also includes other urban characteristics which affect the level of criminal activity. Thus a simultaneous equation model is designed to meet the requirements outlined; it is intended to be useful for urban crime control planning and evaluation, as well as for other areas of urban planning.

In the third section, the details of a comprehensive model necessary to specify these relationships are identified. Included is a discussion of the five sub-systems that the model should include, an analysis of the variables that might be included in each sub-system, or sub-model (with specific reference to past modelling activities), and a discussion of some econometric issues which stem from the model development.

The model is defined in terms of market or system interactions. The system is summarized in five equations, or sub-models:

1. A crime generation or supply of offenses function – a model of criminal activity.
2. A law enforcement production function – a model which describes the output of the criminal justice system.
3. A police services demand function – a model which describes the determinants of police expenditures.
4. A city property value function – an urban property market model.
5. A city revenue function – an urban public finance model.

Each of the sub-systems (equations) is discussed in some detail. The purpose is to identify key determinants of behavior within each sub-system and to identify links among them.

The major hypotheses upon which the model described in this section is based are:

1. The level of crime generated in a urban area is expected to be related to property values, police expenditures, the conviction rate, the arrest rate, average sentence length, income, and indices representing socioeconomic and housing quality factors, in that:
   a. property values and income level represent potential gains to the criminal,

   b. the conviction rate, the arrest rate, and average sentence length represent potential costs to the criminal,
   c. police expenditures represent the independent deterrent effect of law enforcement activities,
   d. the socioeconomic index represents characteristics of the population which directly or indirectly affect gains and costs of criminal behavior,
   e. the housing quality index represents the quality of living conditions in an urban area which affect crime.
2. The conviction rate, a measure of criminal justice output, is expected to be related to total court expenditures, percentage of court expenditures spent on judges, the distribution of expenditures between civil and criminal courts, total expenditures on correctional facilities, the percentage of available penal space which is filled, the level of police expenditures, the percentage of the police budget spent on direct law enforcement, and the crime rate, in that:
   a. the three court expenditure variables represent the ability of the court system to deal with court loads,
   b. the two correctional variables represent constraints, or limitations, on the sentencing ability of judges, and ultimately on the willingness of prosecutors to bring individuals to trial,
   c. the two police expenditure variables represent the supply of potential defendants, as does the level of crime.
3. The level of police expenditures is expected to be related to the level of crime, past crime rates or past police expenditures, the level of available city revenues, and intergovernmental transfers, in that:

a. police expenditures are expected to react to present or past years' crime rates,

b. the present level of police expenditures is limited by previous years' levels, in that change in the city's budget of any line item is normally limited,

c. available revenue from own (city) sources or other sources (intergovernmental transfers) places an absolute upper bound on potential police (or any budget line item) expenditures.

4. The value of property in an urban area is expected to be related to the level of crime, the quality of housing, the quality of available public services, the usage of land in the city, the tax rate, and socioeconomic characteristics of the population, in that:

   a. crime represents a disamenity which reduces the desire to locate in an area, reducing demand for urban property,

   b. the quality of housing, socio-economic factors, and the available public service package represent demand factors for property,

   c. the land use mix represents the differential uses of property which can affect aggregate property values,

   d. the tax rate represents, in part, the cost of owning property which is expected to be capitalized into the value of property.

5. The amount of revenue available to a city is expected to be related to the value of property, the tax rate, tax effort, and other sources of funds, such as intergovernmental transfers, in that:

   a. the property tax is the largest source of own revenue per city and thus the value of property represents potential taxable revenue sources,

   b. the tax rate and tax effort represent both present and future available revenue since higher taxes and efforts constrain future tax increases,

   c. intergovernmental transfers represent potential alternatives to the property tax as sources of city revenue.

In addition to specification of the simultaneous equation model, several methodological issues are raised in Section III in the course of the model development. The problem of potential multicollinearity among the housing quality variables and among the socioeconomic variables is discussed and procedures for overcoming this econometric problem are suggested. The problem of how to measure crime generation, or crime rates "correctly" is highlighted. Alternatives to the use of simple crime rates are briefly presented. Finally, the need for subdivision, or additional equations in the model, is considered and suggested, where appropriate.

The model described is a simultaneous equation model containing a minimum of five equations. The nature of simultaneous equation models is briefly described in Appendix A. In addition, the appendix describes the methodological requirements for obtaining reliable empirical estimates of simultaneous equation systems.

Two other appendices support the discussion in Section III. Appendix B describes how "multipliers" can be derived from the model. The appendix contains an explanation of what the multipliers measure and how they can be used to link the model to various public policy questions or options. Policy variables included in the model are identified. This appendix demonstrates the potential value of the model to criminal justice planners and practitioners, as well as to other public sector decision-makers.

Appendix C summarizes the data requirements of the model. While we do not attempt empirical estimation, it is clear that estimation would be required to give measured content to the sytem described. Appendix C suggests the possibilities for empirical work by outlining the data requirements.

Section IV. SUMMARY AND CONCLUSIONS

The study concludes with a brief summary and discussion of directions for future related research. The accomplishments of the study are highlighted. Three major contributions are noted: 1) provision of a summary of a large number of models of crime, law enforcement and the public sector presented in such a way as to facilitate comparison; 2) criticism of the models reviewed to emphasize their value to public policy formulation; and, 3) development of a comprehensive, policy-relevant model of urban crime, the criminal justice system, and urban public revenues.

INTRODUCTION

This study is an effort to describe the complex interactions between the urban public sector and urban crime. The impact of relatively high crime rates on urban property values, and the resultant interaction with the public sector has not previously been systematically examined, either theoretically or empirically. Yet an examination of this impact is a necessary part of our analysis of urban problems, as well as our development of a comprehensive attack against urban crime, for the ability of the urban public sector to respond to the crime problem in part depends on the resources available to it, more specifically, its tax base. Since the property tax continues to be the prime source of revenue at the local level, even in the largest cities, aggregate urban property values affect the ability of urban centers to maintain law and order within their boundaries. It is the interrelationship between urban crime and the ability of the urban public sector to fight crime which is the focus of this study.

Our purpose is to describe, or model the interactions in terms of a system of simultaneous equations. While methodologically necessary, as we demonstrate, the simultaneous approach has the advantage of stressing the systematic aspects of the interplay of criminal justice agencies in urban settings. Thus, by recognizing both intergovernmental and inter-agency behavioral impacts in a series of interdependent equations, the model highlights the role and importance of agency cooperation within the system.

The central hypothesis of the model is that crime rates affect urban property values. These, in turn, affect urban public revenues, primarily those derived from the property tax, but also any intergovernmental transfers distributed according to tax base. Crime rates may also affect revenues through an impact on conditional transfers distributed specifically for law enforcement. Urban public revenues determine the city budget, including that for police and other local criminal justice expenditures. These expenditures at the local level, as well as expenditures elsewhere both public and private, are likely to affect urban crime rates. They are also likely to be affected by crime rates; thus the crime rate may be a function of the criminal justice budget, but the criminal justice budget may also be a function of the crime rate.

A portion of these interrelationships has been examined previously. However, we are aware of no study which has included the impact of crime on the tax base and city revenues in a comprehensive model. By extending previous analyses to incorporate the complexities of urban public finance, it is possible to obtain a more complete and accurate picture of the interaction between the urban public sector and urban crime. Information from the model can then be used in a variety of ways to facilitate development and evaluation of policies directed toward urban crime control. Criminal justice system constraints imposed by other levels of government which affect the urban system can be identified and the additional policy implications addressed. The role and importance of public sector agency cooperation can be identified.

To develop the model, our method has been to review prototypes of model building efforts and to critique each in terms of its theoretical foundation, empirical content and methodology, and public policy relevance. Section I contains a detailed discussion and evaluation of these models, beginning with Gary Becker's important theoretical paper in 1968, and ending roughly ten years later with a paper by Hellman and Naroff.

Section II of the study summarizes the rather lengthy discussion in Section I. The models are summarized both verbally and in tabular form, significant developments are recognized, and gaps or shortcomings in the model building efforts are identified. Directions in which the models should be extended are indicated. Based on this summary, a general model is described which meets the theoretical and methodological requisites outlined in the section.

In Section III, we present a simultaneous equation model of the interrelationships between urban crime and the urban public sector. The model is defined in terms of market or system interactions. The system of markets is summarized in five equations: a crime generation or supply of offenses function, which describes criminal activity; a law enforcement production function, which describes the output of the criminal justice system; a police services demand function, which describes the determinants of police expenditures; a city revenue function, which describes sources of urban public finances; and a city property value function, which summarizes the operation of the urban property market. Each of the sub-systems (equations) and their component behavioral determinants (variables) is discussed in some detail. The purpose of this discussion is to describe the manner in which the various markets operate, that is, to identify key determinants of behavior within each sub-system and to identify the links among them.

The model described in Section III is not empirically estimated; this is not our purpose. The model is presented in theoretical terms. The purpose is to emphasize the complex interactions between urban crime and the urban public sector, including agency interactions both within and outside of the criminal justice system. The model is described in a set of simultaneous equations. The nature of simultaneous equation models is briefly described in Appendix A. In addition, the appendix describes the methodological requirements for obtaining reliable empirical estimates of simultaneous equation systems.

Two other appendices support the discussion in Section III. Appendix B describes how "multipliers" can be derived from the model. The appendix contains an explanation of what the multipliers measure and how they can be used to link the model to various public policy questions or options. This appendix demonstrates the potential value of the model to criminal justice planners and practitioners, as well as to other public sector decision-makers.

Appendix C summarizes the data requirements of the model. While we do not attempt empirical estimation, it is clear that estimation would be required to give measured content to the system described. Appendix C suggests the possibilities for empirical work by outlining the data requirements.

Section IV briefly summarizes the discussions of the previous sections and presents some concluding remarks.

SECTION I. IDENTIFICATION AND CRITIQUE OF RELEVANT MODELS

In this first section of our study we present a detailed review and description of prototypes of previous related model building efforts. Each model is examined and critiqued in terms of both theoretical and technical qualities, as well as policy relevance. The discussion of the models is arranged in chronological order, which roughly parallels the conceptual development and permits historical comparison. With the exception of the first three models reviewed, which are presented as the foundation upon which later studies built, the models described are restricted to those which contain empirical work. Thus some purely theoretical papers which appeared later are not included.

In reviewing each study we focus on its contribution to the development and empirical estimation of models of the relationships among crime, law enforcement efforts, and public revenues. Some studies examine only part of this picture, while others are more comprehensive. Still others accomplish a great deal more than modelling these relationships and focus on other aspects of the economics of crime. In such cases, our review is restricted to that portion of the study relevant to our purpose. This is not to suggest that the additional contributions of those papers are not important. Our survey includes simultaneous systems models, single equation models, and verbal models.

A. The Becker Model

We begin our review very appropriately with an article written by Gary Becker which appeared in 1968 [2]. This paper accomplishes a great deal and laid the foundation for the study of the economics of crime. The main purpose of the paper is to discuss how many of our scarce economic resources and how much punishment should be used to enforce various laws, i.e., optimum law enforcement. A subsidiary purpose is to present an economic theory of criminal behavior.

1. The Model. Becker's model explores a series of behavioral relationships, each of which becomes incorporated within a mathematical model: 1) the relationship between the number of criminal offenses and the cost of offenses; 2) the relationship between the number of offenses and the punishments given; 3) the relationship between the number of offenses, arrests, and convictions and public expenditures on police and courts; 4) the relationship between the number of convictions and the costs of punishment; and, 5) and the relationship between the number of offenses and private expenditures on protection and apprehension. The later relationship is analyzed separately.[1]

The relationship between the number of offenses and the cost of offenses is summarized in a damages equation:

$$D(O) = H(O) - G(O) \qquad (1)$$

where D(O) = damage to society from offense O

H(O) = harm from offense O

G(O) = social value of the gain from O to the offender

Thus damage to society is equal to the harm from the offense, minus the social value of the gain from the crime to the offender. (It should be noted

[1]In the models reviewed, the role of private production of protection against crime is ignored. It is assumed that demand for crime protection is reflected in public provision. For a discussion and empirical estimation of the substitutability of private and public protection inputs, see C.T. Clotfelter, "Public Services, Private Substitutes, and the Demand for Protection Against Crime," The American Economic Review, Vol. 67, No. 5, December, 1977, pp. 867-877.

that some authors disagree with the inclusion of G(O), arguing there is no social value to the offender's gain.) The damages equation includes only damages from the offense itself. It is not a social losses function which would include social costs of apprehension, conviction and punishment. These are, however, considered by Becker when he defines optimality conditions.

The relationship between the number of offenses and punishments given is defined in a market supply of offenses equation:

$$O = O\ (p, f, u) \qquad (2)$$

where O = number of offenses per time period

p = probability of conviction per offense

f = punishment per offense

u = all other influences on the amount of crime, (e.g., income available in legal and other illegal activities, willingness to commit illegal acts, etc.)

The number of offenses per time period depends on the probability of punishment (conviction) and the severity of the punishment, as well as a large number of other influences summarized by the term u.

The relationship between the number of offenses, arrests and convictions and public expenditures on police and courts is summarized in a cost of apprehension and conviction equation:

$$C = C\ (p, O, a) \qquad (3)$$

where C = costs of apprehension and conviction (police and court costs)

p = probability of conviction

O = number of offenses

a = number of arrests

Police and court costs of apprehension and conviction depend on the probability of conviction, the number of offenses, and the number of arrests. He later drops arrests from the equation and uses simply:

$$C = C\ (p,\ 0) \qquad (4)$$

The relationship between the number of convictions and the costs of imprisonment or other punishment is derived from a punishments equation:

$$f' = bf$$

where f' = the social cost of punishment

f = the cost of the punishment to the offender

b = a coefficient which transforms offender costs into social costs

The punishments equation is really an identity, in which offender punishment costs are transformed, via a coefficient, into social punishment costs. Social costs of punishment are equal to the cost of punishment to offenders, plus the cost (or minus the gain) of punishment to others. The transformation coefficient, b, would assume different values depending on the form of punishment. If fines are used, b is approximately equal to zero, indicating zero social costs. The reason is that the cost to the offender is offset by the gain (revenue) to others. For other forms of punishment, however, b is greater than one, i.e., social costs exceed offender costs.

Using the punishments equation (5), the relationship between the number of convictions and the costs of punishment can be summarized:

$$C^* = bpf0 \qquad (6)$$

where C^* = social cost of punishments

bf = social punishment cost per offense convicted

$p0$ = number of offenses convicted (since 0 is the

number of offenses and p is the probability of conviction)

Becker then combines equations (1), (4) and (6) to construct a social loss function which indicates the total social losses from criminal offenses:

$$L = D(0) + C(p,\ 0) + bpf0 \qquad (7)$$

where L = social loss from offenses

Social losses from criminal offenses are equal to the damage from the offense, itself, plus the costs of apprehension and conviction, plus the social costs of punishment.

Becker uses equation (7) to define optimum values of policy variables to minimize social losses. The policy variables are C, the amount spent to fight crime; f, the punishment given per offense; and b, which summarizes the form of the punishment. These variables, via the supply of offenses equation (2), the cost of apprehension and conviction equation (4), and the damages equation (1), indirectly determine 0, p, and D and, therefore, ultimately determine L.

Becker then adjusts his policy choice variables somewhat for analytical convenience, focusing on values of p (probability of punishment) and f (severity of punishment) to minimize L (social losses from crime). He goes on to examine the optimality conditions, discuss some of the policy implications of his conclusions, extends the analysis to consider private expenditures against crime, and finally suggests and discusses some interesting applications of his approach.

2. Critique. While the Becker paper contributes a great deal to the understanding of criminal choice and optimum law enforcement, there are some theoretical shortcomings in the analysis which have been pointed out by others. Harris [9] argues that Becker's model fails to include the social

losses from wrongful punishments and that the legal framework surrounding the issue of optimum law enforcement is also subject to policy choice.

Stigler [25] rejects Becker's concept of the "social value of criminal gain to the offender," a concept which Becker uses as a limitation on punishment. Stigler introduces another source of limitation -- the need for marginal punishment costs to achieve marginal deterrence. (Excessive punishments for minor crimes leave no worse punishments to deter more serious offenses). In addition, Stigler argues, as does Harris, that social costs of law enforcement must include the costs of punishing innocent parties.

Ehrlich [6] (discussed below) builds on the Becker model by developing a theoretical construct which responds to some of the limitations Ehrlich identifies in the Becker framework. Specifically, theoretical limitations addressed by Ehrlich are: 1) the inclusion of only punishment costs in the supply of offenses behavioral relation (except in a very casual way, i.e., the summary term). Ehrlich explicitly considers both costs and gains from legal and illegal activities; 2) the treatment of legal and illegal activities as mutually exclusive choices. Ehrlich argues that the choice to commit criminal acts does not imply that legal sector employment is not also possible -- the rational individual will allocate time among legal market activity, illegal market activity, and consumption (which includes leisure); 3) the need to distinguish between the deterrent and preventive (incapacitation) effects of punishment by imprisonment. The distinction is important from a policy perspective since the costs of the latter far exceed those of the former; and, finally 4) the need to analyze the interaction between "offense and defense", i.e., between crime and collective law enforcement activity.

It should be noted that while Becker develops a simultaneous system of equations in which the interaction between offense and defense is implied, he does not empirically estimate the model, as Ehrlich does, and, more importantly, from a theoretical perspective, the Becker interaction is couched in terms of "costs", rather than "expenditures". While this distinction may not appear important, it implies a lack of deliberate choice with respect to expenditures for defense against crime. "Costs" are simply reactive; "expenditures" suggest policy decisions. Thus, the policy variables identified by Becker are the probability of punishment and the severity of punishment. Public expenditures on law enforcement are not included as a policy variable.

Nor is the feedback effect of the amount of crime on the ability to spend on law enforcement considered in the Becker model. Public sector activities, including both revenue raising and expenditures decisions, are not explicit. While the probability of punishment is included as a policy variable, there is no definition of how this probability is changed, other than via the cost function (equation 4). There is no production function concept underlying the behavioral relation between police and court costs of apprehension and conviction, on the one hand, and the probability of conviction on the other. Thus in terms of practical policy making decisions, the Becker model has limited applicability.

Perhaps some of these criticisms are understandable given Becker's purpose. His focus is on defining optimum law enforcement which will minimize social losses from both crime and enforcement. There is no particular geographical or political jurisdictional definition of the decision-making unit. The discussion is general, global and abstract. No empirical counterpart to the theoretical equations is provided. No estimation of the parameters of the model is intended, or attempted.

The supply of offenses equation is a good example [equation (2)]. All other factors which affect the supply of offenses, other than the probability and severity of punishment, are summarized in one term. In a theoretical model this is perfectly acceptable. If, however, the model is to be empirically estimated and policy relevant, the additional factors must be spelled out and given some practical, measurable identity. Imbedded within the summary term may be additional policy variables which must be made explicit.

The comments made here have largely focused on the lack of an empirical/policy emphasis in the Becker model. The theoretical construct nevertheless laid the foundation for additional theoretical and empirical work analyzing the relationships among crime, law enforcement, and public revenues.

B. The Katzman Model

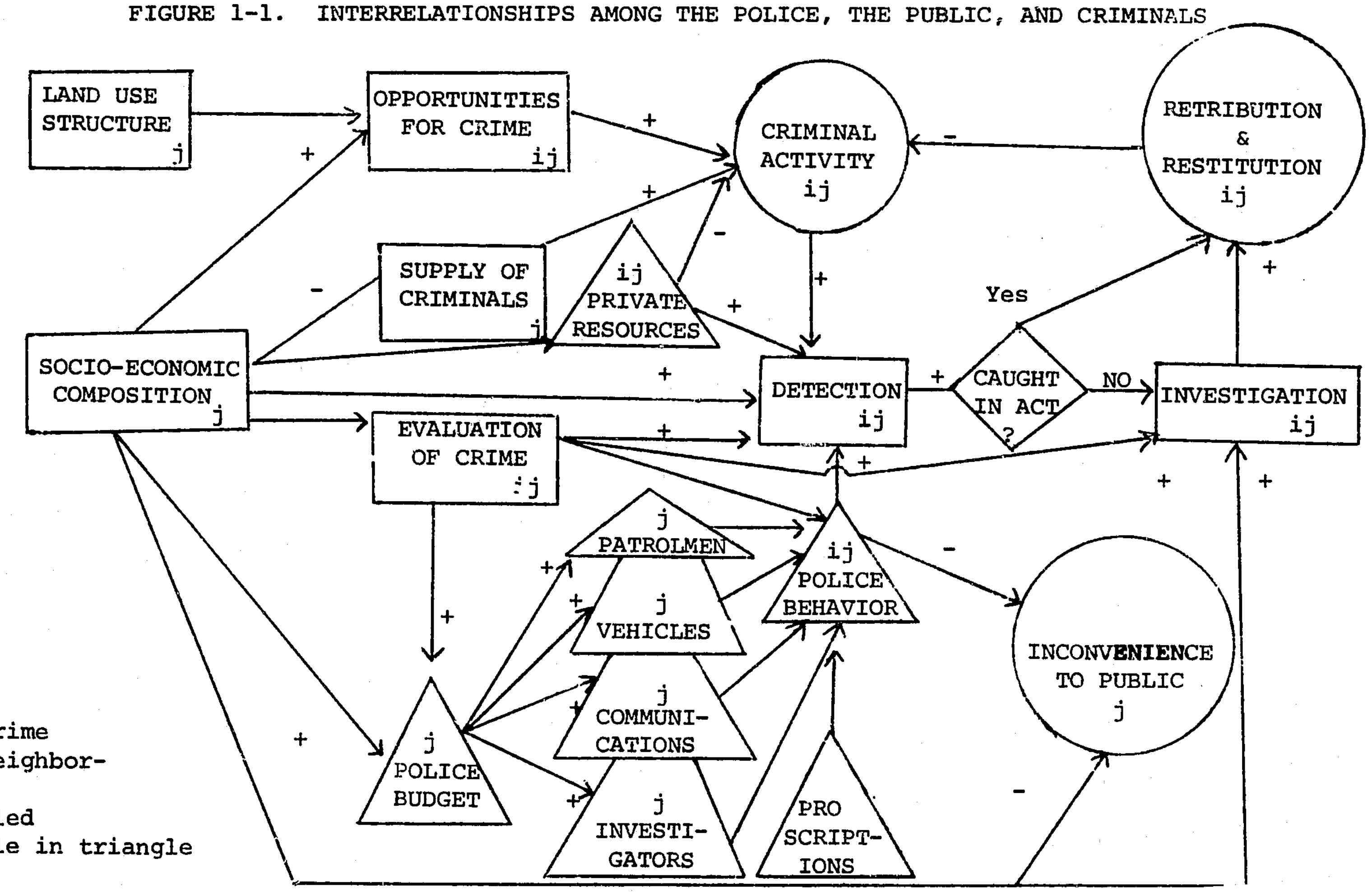
1. <u>The Model</u>. The Katzman model which appeared in 1968 [13], shortly after the appearance of Becker's paper, is almost a direct contrast to that of Becker. The Katzman model is essentially a verbal one. His purpose is to identify the economic choices which society must make in deterring crime. He summarizes these choices in a schematic which describes a series of simultaneous relationships among activities of the public, criminals, and the police. He focuses on activities of the police (as opposed to other segments of the criminal justice system) and identifies the internal resource allocation decisions which must be made there, including allocative choices among neighborhoods, classes of crime, police programs, and police inputs.

The Katzman model has a geographical and political jurisdictional focus -- an urban area. Policy variables are given practical, measurable identities and choices are indicated. Policy variables and choices include: private sector resources allocated to the deterrence and detection of criminal activity; the police budget and allocation of that budget over neighborhoods, programs and activities, and types of police inputs; police behavior by crime and by neighborhood, which in part is affected by budget decisions; and proscriptions on police behavior. The summary schematic is reproduced in Figure 1-1.

While the interrelationships described in the schematic are not measured, the model is empirically and policy oriented -- the police budget is made explicit; expenditure categories and choices are defined; a police production function is described, if not made explicit; the impact of socio-economic characteristics on the demand for police services and the supply of criminal offenses is indicated; the effect of land use structure on opportunities for crime is incorporated; and policy choices other than law enforcement activity are indicated. While not complete, the Katzman model seems real.

2. <u>Critique</u>. Nevertheless, improvements are possible and necessary. An obvious improvement would be specification of the relationships in mathematical equations which could be empirically estimated. Rational policy decisions cannot be made unless some sort of numbers are indicated. While Katzman concludes that little quantitative knowledge of the relationships described in his schematic is available, progress has been made since publication of his paper in both measurement and estimation. Mathematization in a simultaneous equation system would therefore be useful.

FIGURE 1-1. INTERRELATIONSHIPS AMONG THE POLICE, THE PUBLIC, AND CRIMINALS



i = type of crime
j = type of neighbor-hood
output encircled
policy variable in triangle

Again, urban public sector activities and choices could be more completely described, and constraints imposed by other levels of government could be identified under proscriptions. The impact of criminal activity on the demand for law enforcement, as well as on land use structure and property values should be included. The latter affects urban public revenues and therefore the size of the police budget. This criticism is shared by the Becker model, as well as most of the other models described below. As we shall see, omission of the consideration of the impact of crime on land use and property values is a common shortcoming and the primary one which our research has sought to remedy. In a sense the Katzman model comes closest to satisfying the need to include the feedback effect of crime on property values, tax revenues and police budgets by at least including land use structure as a relevant urban characteristic. His inclusion, however, is limited to its direct impact on crime generation.

C. The Blumstein and Larson Model

A year after publication of the Becker and Katzman papers, a related model of the criminal justice system appeared from another direction-operations research [3]. The intention of the Blumstein and Larson paper, which builds on earlier work by both themselves and others is to describe a complete criminal justice system which includes interactions among police, prosecution, courts, corrections, and criminal activity. Both the Becker and Katzman papers fail to consider, in more than a cursory way, interactions within the total criminal justice system.

1. The Model. The Blumstein and Larson model, more so than Katzman, is empirically policy oriented. They argue that, at a minimum, their model

identifies data needs and research questions which must be grappled with in order for assessment of the crime consequences of various actions taken within the criminal justice system to be possible. Their model is in part a response to the need for comprehensive statewide planning for improvement in law enforcement indicated by federal funding to state planning agencies for this purpose provided by the Omnibus Safe Streets and Crime Control Act of 1968.

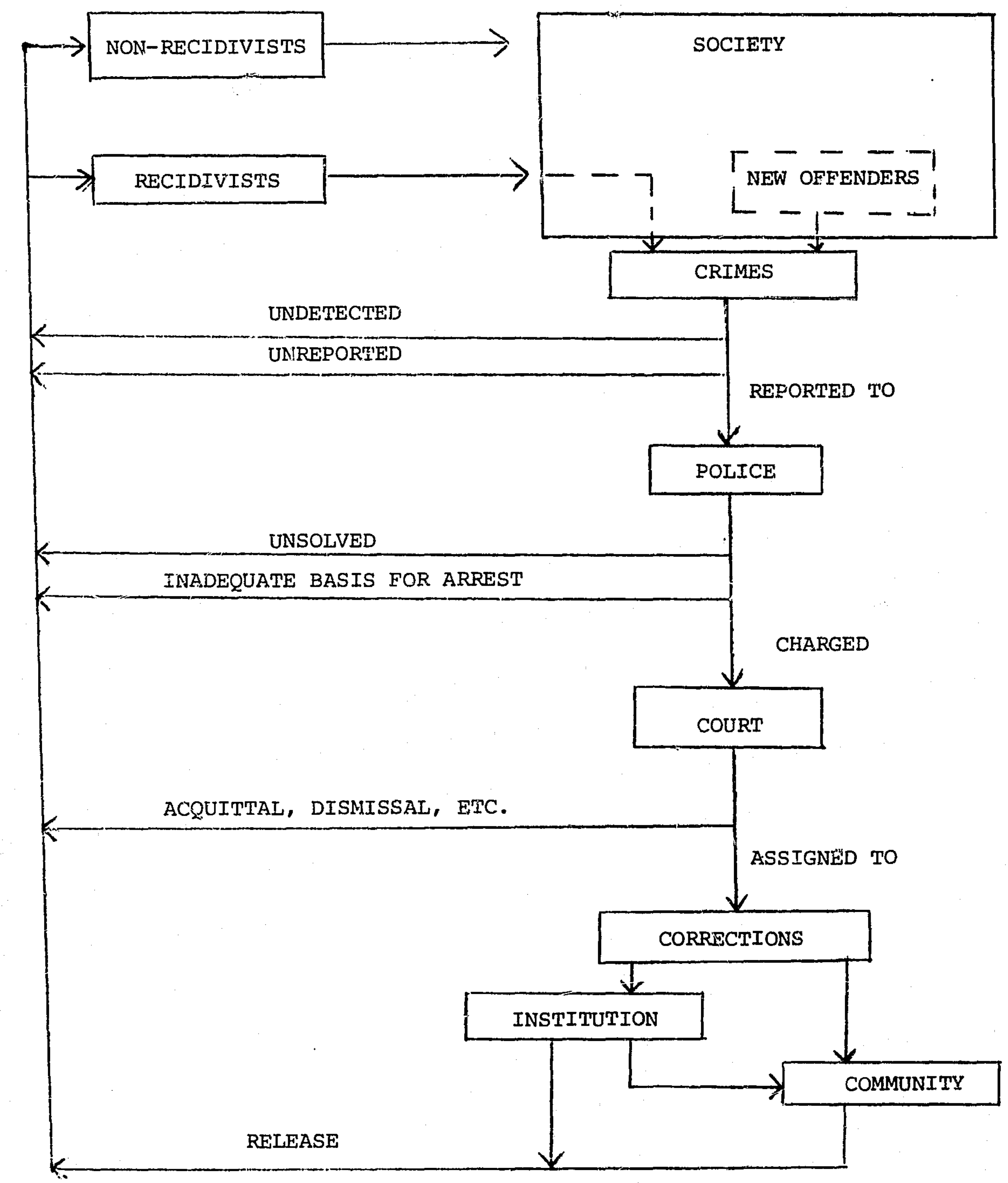
Blumstein and Larson begin with a schematic which describes the total criminal justice system. This schematic is reproduced in Figure 1-2. From the description, two modelling approaches are identified: a linear model and a feedback model.

The Linear Model. The linear model traces the flow of persons through each processing stage in the system, identified by each of the seven Index crimes. The input to the model is the number of each of the Index crimes reported to the police during one year. The outputs are computed annual flows through each processing stage, costs of processing, and manpower requirements at each stage. Each processing stage is characterized by various cost rates per unit flow, as well as branching probabilities.

The model permits assignment of workloads, manpower requirements and costs to each type of crime, and projections of future values of these variables based on estimated future arrest rates. The model can also be used to determine the impact that changes in one subsystem has on the workload, manpower requirements and costs of another subsystem.

The Feedback Model. The feedback model, while more aggregated, incorporates the recidivism probability associated with each released defendant at each possible point of dismissal from the criminal justice system, and the

FIGURE 1-2. DESCRIPTION OF THE CRIMINAL JUSTICE SYSTEM



subsequent processing for future arrests. The model identifies flows through the system by crime type and offender's age. The latter is necessary to incorporate the recidivism feedback effect. The input to the model is the number of arrests during a year, by crime and age of offender arrested, for individuals with no prior arrests for the crimes considered in the model (Index crimes). Arrests then proceed through the system, as in the linear model. In order to incorporate the feedback effect, it is necessary to include the probability of rearrest at each possible point of dismissal from the system (a function of age and prior record), the distribution of delay between release and next arrest (to determine age at rearrest), and a crime-switch determiner to identify crime type of next arrest.

Given the age of an offender at first arrest and the type of crime arrested for, the model can generate an expected criminal career profile. Using costs from the linear model, system costs of a total criminal career can be estimated. The model also permits assessment of the consequences of alternative actions within the criminal justice system to reduce recidivism probabilities.

2. Critique. The model(s) developed, as the authors argue, is oversimplified. However, as the description of the criminal justice system becomes more detailed, data requirements become impossible. Within the paper the authors show some results of application of their model to the California system, which according to the authors is the only state with close to an adequate data base for their purposes.

The model also makes some simplifying assumptions, in part dictated by data availability. All costs are assumed to be variable and proportional to flow. All variables, e.g., branching probabilities, are assumed constant

through time and independent of each other, as well as independent of factors outside the model (exogenous variables).

Nevertheless, the model describes at least some of the complex interactions among sectors of the criminal justice system and the impact which that system can have on future flows of criminals. It is for this reason that the Blumstein-Larson model is included here. The model does not, however, indicate interactions among the criminal justice system and other public and private sector activities which affect the amount of criminal behavior, nor the impacts which these other activities can have on some of the parameters of the criminal justice system model, e.g., the probability that a crime is detected or reported. The model also fails to incorporate the deterrent effects of the criminal justice system -- an impact which is emphasized in most of the other modelling efforts described here.

Finally, from an economic decision-making perspective, the model fails to consider cost constraints. While criminal justice system costs can be calculated using the model, the manner in which the expenditures are financed, and the governmental unit which bears the cost, or decides whether or not the expenditures are warranted, are not described. Necessary economic choices are therefore not reflected in the model. It should be noted, of course, that the model was not intended as an economic one. However, the authors conclude their paper by arguing that one end goal of studies such as theirs is to improve the allocation of public resources to control crime.

D. The Orsagh Model

The Orsagh model was presented at the Western Economic Association meetings in 1970 [18]. While building on the theoretical model developed by Becker [2], Orsagh blends this approach with a synthesis of partial theories and empirical results drawn from a large body of social science and criminology literature. Thus Orsagh reviews a substantial number of earlier studies in an effort to develop empirical counterparts for the theoretical concepts contained in his model. While Orsagh's model is more aggregated than that of Katzman [13], it shares its empirical emphasis. Katzman, however, does not measure the interrelationships described in his schematic, perhaps because of the complexity of the interactions sketched in his model of urban areas. Orsagh estimates his model using large city and county-level data in California. Orsagh's is the first comprehensive model of crime, sanctions and law enforcement with an empirical focus.[2]

1. The Model. The Orsagh model contains three equations: a supply of offenses function, a police production function, and a public demand for police services function. The theoretical framework on which the empirical work builds can therefore be represented as:

$$O = O\ (p,\ u) \qquad (8)$$

where O = number of offenses, or crime rate

p = probability of punishment (sanctions)

u = all other influences on the amount of crime

This is the supply of offenses equation, which in concept is similar to Becker's equation (2). While Orsagh's discussion and description of equation (8) focuses on "sanctions", which seems to include both probability of punishment, p, and severity of punishment, f [see equation (2)], his empirical work

[2] In a 1973 paper, using a similar model and data base, Orsagh focuses on methodological issues, in particular the need for a simultaneous system approach. See T. Orsagh, "Crime, Sanctions and Scientific Explanation," The Journal of Criminal Law and Criminology, Vol. 64, No. 3, September, 1973, pp. 354-361.

focuses on only risk, or probability of punishment.

A police production function is the second equation in the model:

$$p = p\ (PL,\ O,\ z) \qquad (9)$$

where p = probability of punishment (sanctions)

PL = police labor inputs

O = crime rate

z = all other influences on police productivity

Police output, measured in terms of probability of punishment, is expected to increase with increases in police inputs, and to decrease with increases in the crime rate, all other things being equal. Those other factors are summarized in z.

The last equation is a public demand for police services function, or a police input function:

$$PL = PL\ (O,\ x) \qquad (10)$$

where PL = police labor inputs

O = crime rate

x = all other influences on the demand for police services

Police inputs are expected to increase in response to increases in the crime rate, as well as be affected by other influences summarized in x.

For the empirical work, Orsagh replaces u in equation (8), z in equation (9), and x in equation (10) with sets of variables suggested by the earlier theoretical and empirical work which he reviews. For the most part, Orsagh does not present *a priori* expectations of the signs of the relationships, other than those cited above. Rather, he is testing the sometimes conflicting arguments and results of others. The supply of offenses equation becomes:

$O = O(p, S, Ec, Ch, A, NW)$ (11)

where p = the probability of punishment, measured as probability of sentence of at least six months

S = index of urbanization

Ec = economic well-being, measured as a combination of poverty, infant mortality, education, unemployment, and income inequality

Ch = change, measured as a combination of change in the labor force, population movement, and change in the percentage population black

A = proportion population aged 15-35

NW = percent black

The police production function becomes:

$p = p(PL, O, Sz, A, NW, Pov)$ (12)

where p = probability of punishment

PL = police labor inputs, per capita

O = crime rate

Sz = community size

A = proportion population aged 15-35

NW = percent black

Pov = percent poverty

Finally, the demand for police service function, or police input function is represented as:

$PL = PL(O, Gs, Tx, Y)$ (13)

where PL = police labor inputs, per capita (which Orsagh argues is an index of police expenditures)

O = crime rate

Gs = retail sales of gasoline, per capita (index of demand for police traffic supervision)

Tx = per capita property taxes

Y = average income

Thus demand for service is measured in terms of units of inputs, rather than expenditures, as in some of the other models described below. [See Ehrlich's equation (29), Greenwood and Wadycki's equation (33), and McPheter and Stronge's equation (34)]. The variables Orsagh adds to the police input equation (13) are of some interest. Gs, retail sales of gasoline is included as a measure of public demand for police services other than law enforcement. Given a certain crime rate, O, police inputs would be expected to increase if the demand for traffic control, measured by Gs, were to increase. Tx, the property tax variable, measures two things. On the one hand, it measures a community's ability to buy police services -- its fiscal capacity. On the other hand, it is also an index of potential losses from property crime, a factor which would tend to increase the demand for certain police services. The income variable, Y, may measure some of the same things that Tx does.

The three equations were estimated using large city (population over 100,000) and county data for California in 1960. Estimates were derived for six definitions of crime: total index crimes, crimes against persons, crimes against property, and for each of the three types of crime against property. Estimates were obtained using two different statistical techniques -- a single equation method and a simultaneous system method (two stage least squares). Below we summarize those variables found significant in each of the equations when estimated via the preferred, simultaneous method:

Variable	Sign of Estimated Relationship
Supply of Offenses Equation [equation (11)]:	
S, index or urbanization	+
NW, percent black	+ (crimes against persons only)
Output Equation [equation (12)]:	
PL, police labor inputs, per capita	+
NW, percent black	+
Pov, percent poverty	+
Demand for Police Equation [equation (13)]:	
O, crime rate	+
Tx, per capita property taxes	+

and less significant:

Gs, index of demand for police traffic supervision	+

Thus the crime rate appears to be very dependent upon the degree of urbanization (contrast this result with that of Pressman and Carol [23] and Phillips and Votey [21] below), is not dependent on economic well-being, and is not dependent upon race, except for crimes against persons. The insignificance of economic well-being is a result inconsistent with a priori expectations and the results of other studies described below. The result leads Orsagh to conclude that fighting crime by reducing poverty or unemployment may be bad public policy. It is interesting to note, however, that the probability of punishment, measured by the probability of being sentenced

for a term of at least six months, is also insignificant in the supply of offenses equation. This, too, is inconsistent with expectations and the results of some other studies reported here.[3] This suggests that not only are efforts to reduce poverty and unemployment bad policy for fighting crime, but also that law enforcement approaches are ineffective. The policy implications of Orsagh's results are somewhat discouraging. However, keep in mind that severity of punishment was not included in his analysis.

Police productivity, as measured by the probability of being sentenced, was found to be positively related to race and poverty, an interesting result which suggests that lower income individuals and blacks do not have equal access to justice within the criminal justice system. The insignificance of the crime rate variable is surprising.

Finally, the results of estimating the police demand equation pretty much confirm expectations.

2. Critique. The Orsagh model represents the first comprehensive model of crime and law enforcement with an empirical focus. While the results of empirical estimation of the model are disappointing, perhaps because of improperly measured or specified variables, the attempt to quantify the systematic interactions between crime and law enforcement activity, while recognizing the simultaneous nature of that interaction, is a contribution.

In addition, the Orsagh model incorporates the concept of a production function for police, and recognizes the constraint of community fiscal capacity on its ability to provide police inputs, and therefore output of

[3] One possible consideration is the importance of the ratio of criminal offenses to number of offenders. Other things being equal, an increase in the probability of punishment (however measured) may have a more measurable impact on the number of offenses if the offenses/offenders ratio is high. This comment holds for other models reviewed below and, perhaps, for other policy variables.

law enforcement. By doing this, Orsagh makes his model more policy relevant than, e.g., that of Becker. Nevertheless, the Orsagh results are discouraging and the model requires refinement. While Orsagh's model appears similar to that of Ehrlich, described below, it does not share its sophistication in both theoretical content and empirical methodology.

E. Single Equation Empirical Models

Shortly after the appearance of thse very different models of the interaction between crime and law enforcement and the criminal justice system, there appeared a few single equation models which are very empirically oriented. These models contain little or no theoretical development of the interaction between crime and law enforcement; however, such a model is implied in the equation which is empirically estimated. For this reason, a few of the single equation empirical models are reviewed here.

1. Pressman and Carol. The Pressman and Carol paper addresses the question of whether urban crime is a manifestation of an external diseconomy of urban scale [23]. Urbanization takes place in order to take advantage of external economies of urban scale. However, at some point, economies of scale are exhausted and diseconomies of scale are generated. Their hypothesis is that increasing crime rates in urban areas is one reflection of external diseconomies. The purpose of their paper is to test this hypothesis.

The test consists of a cross-sectional partial correlation analysis of the relationship between crime rates in 95 SMSA's in 1965, and "scale" of the SMSA's, as well as other characteristics of the SMSA's which are likely to affect crime rates. They therefore imply a single equation model which we can summarize as:

$$O = O(S,\ u) \qquad (14)$$

where O = crime rate in the SMSA

S = scale of the SMSA

u = all other influences on the amount of crime in the SMSA

Their model therefore includes, although not explicitly, simply a crime generation, or supply of offenses function. Scale is measured in two ways -- population density and net in-migration rates. Other influences (variables) included in the equation are: income levels and distribution, educational level, racial mix, percentage population residing in poverty areas, climate, and number of full-time police relative to population. [Similar to Orsagh's equation (11). Note, too, Orsagh's inclusion of a scale-type variable.]

Results of the partial correlation analysis suggest that population density does not have a significant impact on crime rates, but that in-migration does, particularly on rates of property crime. Thus their hypothesis is in part confirmed. They suggest that problems in accurately measuring density may explain insignificance of that variable in the equation.

While there is some attempt to define the policy relevance of the model and results, the model is quite limited. Most obviously, the model does not account for the simultaneous relationship between crime rates and number of police. Just as the number of police affect the amount of crime, the reverse is also likely to be true. In addition, the model fails to consider the public sector which provides police services. Where do public revenues come from to finance police services, and how are these affected by crime? Inadequate description of the public sector is a criticism common to most of the models reviewed here. Finally, since the model analyzes crime rates in SMSA's, rather than central cities, the focus is not on a single decision-making unit. The policy relevance of the model and results are therefore limited.

2. Allison. The Allison model appeared about one year after publication of the Pressman and Carol paper [1]. The purpose of the paper is simple -- to test the usefulness of those social and economic factors listed by the FBI in the introduction to Uniform Crime Reports in predicting crime rates. The factors listed are supported by findings of the Commission on the Causes and Prevention of Violence: density and size of the community's population and the metropolitan area of which it is a part; composition of the population with respect to age, sex, and race; economic status and mores of the population; relative stability of the population including commuters, seasonal, and other transient types; climate; educational, recreational, and religious characteristics; effective strength of the police force; policies of the prosecuting officials and the courts; attitude of the public toward law enforcement problems; and administrative and investigative efficiency of the local law enforcement agency.

There is no theoretical construct presented to justify selection of the factors, nor hypotheses concerning magnitudes or directions of causal effects. The factors are tested using multiple regression analysis of the relationship between the crime rate in a community and a list of fourteen measurable counterparts to the factors. Data are for 1960 for Chicago and communities within the immediate Chicago area with population in excess of 25,000. Results of estimating the crime generation, or supply of offenses function show that the six most important variables are:

$$O = O(Un, M, A, Sc, Pk, Di) \quad (15)$$

where O = crime rate in the community

Un = unemployment rate (+)

M = proportion of males (+)

A = proportion of young people (+)

Sc = mean number of years of schooling (+)

Pk = expenditures for parks and recreation (-)

Di = distance from the city (-)

The sign of the estimated impact of each variable on the crime rate is indicated in parentheses.

One notable result is the lack of significance of either of two measures of police protection (per capita expenditures and per capita employees). One reason for this result may be the failure once again to account for the simultaneity of the relationship between crime rates and police employment or expenditure. The Allison model shares this, and other criticisms made of the Pressman and Carol model. It is simply not a very sophisticated investigation of the complex nature of the relationships among crime and community characteristics, including the public sector of that community.

3. Sjoquist. The Sjoquist model [24], the last of the single equation models which we review here, is the most sophisticated. The research for the paper was supported by the National Institute of Law Enforcement and Criminal Justice. Sjoquist begins by presenting a theoretical model of criminal behavior (focusing on crimes against property) following along the lines of Becker. The rational criminal considers both psychic and financial gains and costs of criminal and non-criminal activities, i.e., crimes against property and work in the legal sector. Thus, unlike Pressman and Carol or

Allison, Sjoquist's empirical work rests on a theoretical model of criminal choice.

The theoretical model -- a crime generation equation -- is tested using property crime rates in 1968 for 53 municipalities. Results are therefore relevant for policy making at the municipal level (although not all variables included in the model are measured for the municipality alone, as noted below). The supply of offenses equation can be recast using our symbols:

$$O = O(p, f, W_l, W_c, NW, Sc, D, P) \qquad (16)$$

where O = property crime rate

p = probability of punishment

f = punishment per offense (average sentence served, state-wide)

W_l = legal gains (wage) per time period (measured by annual income, county-wide)

W_c = illegal gains (wage) per time period (proxied by average retail sales per establishment)

NW = percent nonwhite

Sc = mean number of years of schooling

D = population density (scale)

P = population

The last six variables of equation (16) would be captured by Becker's u term [equation (2).]. Also notice some similarities with the Orsagh, Pressman and Carol, and Allison models in terms of variables included for empirical testing. Sjoquist, however, is more comprehensive and more sophisticated than the other single equation models.

The probability of punishment is measured in three separate ways: the probability of arrest (ratio of arrests to number of crimes), the probability of conviction (ratio of convictions to number of crimes), and the probability of conviction, given that an arrest is made (ratio of convictions to arrests). In addition, the legal gain variable is supplemented by two additional measures of opportunity cost to the criminal -- the unemployment rate and the percentage of families below the poverty line. This is because the community income variable does not distinguish between incomes of potential criminals and incomes of potential victims. It is therefore not clear whether it measures gains or costs of engaging in criminal activity.

Multiple regression analysis estimates of the relationship between crime and each of the crime generation variables indicates that the following variables are significantly associated with municipal crime rates (the sign of the relationship is indicated to the right):

Variable	Relationship with Crime Rate
p, the probability of punishment (measured in any of the three ways)	-
f, average punishment	-
NW, percent nonwhite	+
Sc, average schooling	+
P, population	+
Un, unemployment rate	+

Some of these results are consistent with other studies. Of the significant variables, only the schooling variable appears to have the wrong sign. This may be because it is not clear what this variable really measures. The insignificance of both the legal and illegal gain variables may be due to measurement problems.

The Sjoquist model, while the best of the single equation models reviewed, still suffers from the single equation approach -- it does not capture the two-way causality between crime and law enforcement variables, even when measured in terms of law enforcement outputs rather than inputs, i.e., probability of punishment rather than number of police. The budgetary and production processes underlying the provision of law enforcement is masked in this kind of model. Public sector decisions and policy options are therefore hidden.

F. The Phillips and Votey Model

The Phillips and Votey model [20], which was actually published a few months prior to the Sjoquist paper, represents a return to a simultaneous system approach. Like Sjoquist's work, the research for the model was supported by the National Institute of Law Enforcement and Criminal Justice.

1. The Model. The model as it is presented is primarily a verbal model, supported by schematics, and supplemented by graphical descriptions of functions within the simultaneous system. The purpose of the study is to analyze 1) the processes which generate crime; 2) the productivity of law enforcement agencies; and 3) the links between the two processes. Thus the model recognizes the interaction between crime generation and law enforcement, a commonly omitted feature of the single equation approaches. In this sense it is similar to the Orsagh model. The Phillips and Votey contribution is to show not only that law enforcement responds to crime, but also that crime

responds to law enforcement via a deterrent effect. To illustrate this interaction is their primary purpose.

A schematic summary of their model is contained in Figure 1-3. It shows that the level and effectiveness of law enforcement activity is determined by technology, expenditures, and the number of criminal offenses. Law enforcement level and effectiveness (output) is described in terms of crimes cleared by arrest. These, with the additional impact of the judicial and corrections system, affect the amount of crime generated via a deterrent effect. Other factors, such as attitudes and economic conditions, also affect offense rates.

The empirical work in the paper is restricted to separate analysis of the crime generation process and the law enforcement production process, and the results are then synthesized into an interacting system. The empirical work is supported by theoretical models. The model of crime generation is a Becker-type criminal choice model. The time series analysis of crimes against property analyzes subsets of the population classified by age, race, and sex. They find that lack of economic opportunities (jobs or school) is strongly associated with youth arrest rates.

The model of the law enforcement production process is described in a schematic, reproduced in Figure 1-4. Output is defined in terms of clearance rates. Raw input to the production process is the offense rate. Given input prices, law enforcement expenditures determine the amount of labor, capital and other inputs which can operate on the offense rate to produce crimes cleared by arrest. Based on some of their earlier work, they present estimates of the elasticity of crimes cleared by arrest with respect to police personnel, other law enforcement expenditure, and offenses. The

FIGURE 1-3. SCHEMATIC DIAGRAM OF THE CRIMINAL JUSTICE SYSTEM

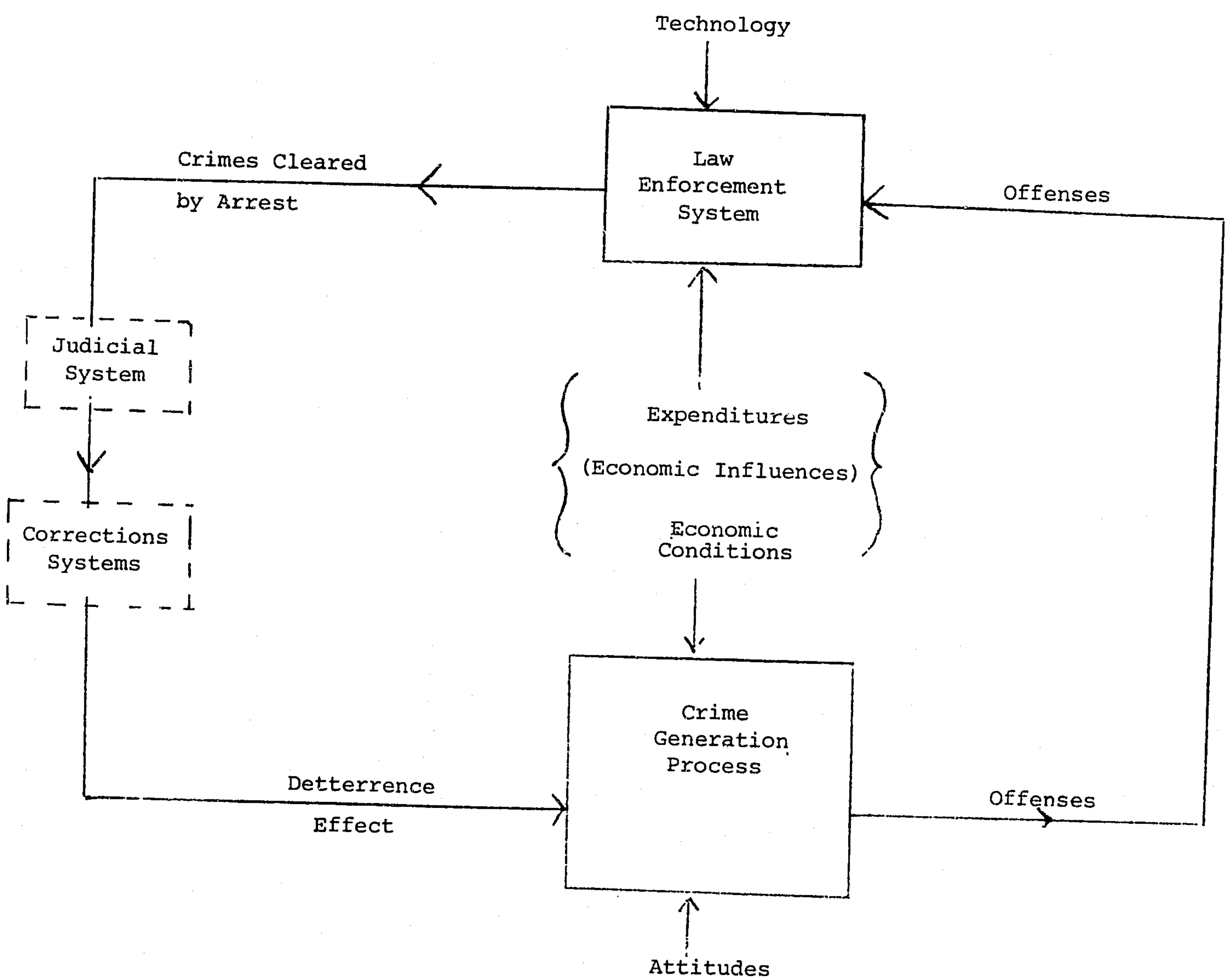
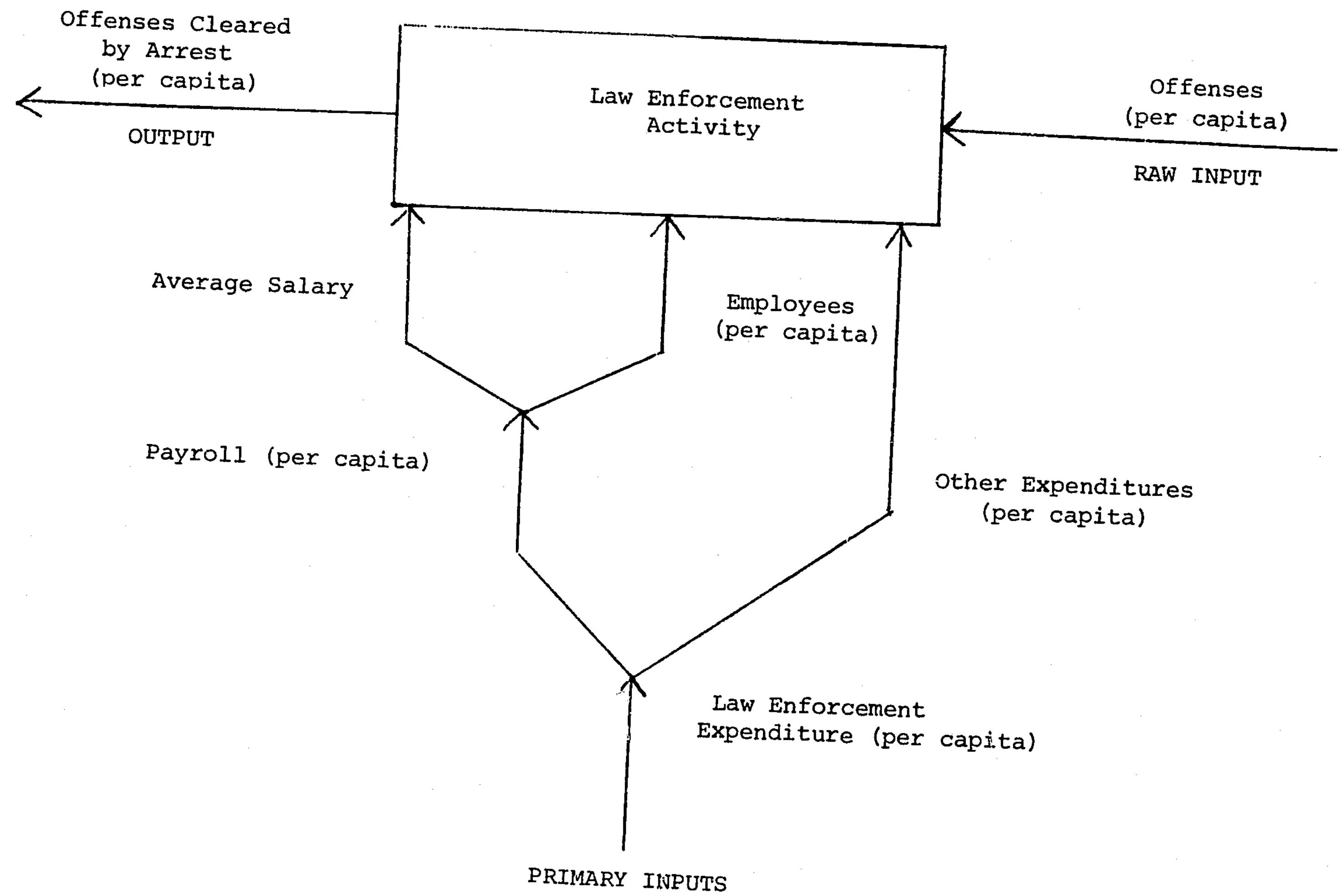


FIGURE 1-4. SCHEMATIC DIAGRAM OF A LAW ENFORCEMENT PRODUCTION PROCESS



elasticities measure the percentage change in output, or crimes cleared by arrest, for a one percent change in one of the inputs.

The crime generation process and the law enforcement production process are then combined to illustrate a simultaneous system in a series of graphical descriptions of various combinations of crime generation and law enforcement production functions, plotted against the clearance ratio and the offense rate.

The Phillips and Votey model can be expressed in mathematical terms as a two equation-simultaneous system. Each of the two processes, crime generation and law enforcement production, can be described in functional form. The model therefore contains a supply of offenses function and a law enforcement production function which can be expressed as:

$$O = O(CR, u) \qquad (17)$$

$$CR = CR(O, E, T) \qquad (18)$$

where O = offense rate

CR = clearance rate (this can be thought of as analagous to Becker's probability of punishment, p)

u = all other influences on the amount of crime, including economic conditions and attitudes

E = law enforcement expenditures

T = technology

The empirical counterparts to the variables described in the system above are suggested by earlier work by Phillips and Votey, described in a footnote to the paper:

$$O = O\ (CR, Un \cdot L, t) \qquad (19)$$

$$CR = CR\ (O, E, t) \qquad (20)$$

where Un = unemployment rate

L = labor force participation rate

t = time

In the supply of offenses function, Un · L and t are substituted for u. Economic conditions are summarized by the product of the unemployment rate and the labor force participation rate. Changing social attitudes are proxied by a time variable. In the production function, time is used to measure changes in technology. The supply of offenses equation can be compared with several others described above, while the production function can be compared with Orsagh's equation (12).

In a later paper, which contains a more well-developed theoretical model, Phillips and Votey expand on the model described above by focusing on the demand for law enforcement manpower [21]. Rather than expressing the law enforcement production function, equation (20), as a function of expenditures, they express it as a function of labor inputs. The demand for labor inputs, then, is explained in terms of a community's desire to minimize the sum of losses to crime and the costs of crime control. The cost of control depends, in part, on wages of law enforcement personnel. Phillips and Votey complete their model by considering the possibility that the supply of law enforcement labor is not perfectly elastic and that, therefore, law enforcement wages are not a constant (i.e., exogenous to the model). This possibility is accounted for by including a wage function. The expanded model can be expressed as:

$$O = O\ (p, f_1, f_2, u) \qquad (21)$$

$$p = p\ (O, PL) \qquad (22)$$

$$PL = PL\ (W, O, Y, CM) \qquad (23)$$

$$W = W\ (PL, Y, D) \qquad (24)$$

where p = probability of punishment (measured by the conviction rate)

f_1, f_2 = severity of punishment, measured by the fraction of convictions resulting in severe committments (a measure of felony sentences) and the fraction of felony sentences which are probation with jail, respectively

PL = law enforcement personnel, per capita

W = law enforcement wages

Y = median income

CM = crime mix (the ratio of nonviolent to violent crime)

D = population density

Equation (22) differs from (20) by the substitution of labor inputs (PL) for expenditures (E). The time variable is also dropped because the data base used to estimate the second model is cross-sectional.

The demand for law enforcement labor inputs, equation (23), is hypothesized to be a function of the wage paid for labor inputs (W, a measure of the costs of crime control) and of the benefits derived from law enforcement. The latter depends on the crime rate (O) and on the average loss involved in a felony crime. Average loss is proxied by two measures: Y, median income in the community, and CM, the crime mix.

In the law enforcement wage equation, (24), wages are a function of labor input (PL), median income (Y) and population density (D). The latter two variables are included as proxies for wages in other occupations -- Y as a measure of the cost of living, and D as a measure of the urban/rural

nature of the community. Finally, if the supply of labor is less than perfectly elastic, wages will increase as more labor is employed, i.e., the coefficient of PL will be positive and significant.

The model is estimated using both ordinary least squares and two stage least squares techniques, with roughly similar results, at least with respect to coefficient signs and significance. The data base consists of fifty observations on California counties in 1966. Before estimation, the u term in equation (21) was replaced by five uncorrelated indices defined through principal components analysis. (For principal components analysis, see the discussion of the McPheters and Stronge model below. They used the technique prior to Phillips and Votey.) The five indices tried in equation (21) are combinations of 12 socio-economic variables: u_1, a measure of how urban a county is; u_2, an index of poverty; u_3, a measure of the presence of disadvantaged youth; u_4, an index of frustrated economic ambition; and, u_5, a measure of change or instability.

Results of the estimation process indicate that the following variables are statistically significant:

Variable	Sign of Estimated Relationship
Supply of Offenses Equation [equation (21)]:	
p, probability of punishment (conviction rate)	-
f_1, severity of punishment (fraction of convictions resulting in severe committments)	-
u_4, index of frustrated economic ambition	+
Production Function [equation (22)]:	
O, crime rate (seven index crimes)	-
PL, law enforcement personnel, per capita	+

Input Equation [equation (23)]:

O, crime rate	+
W, law enforcement wage	-

Wage Equation [equation (24)]:

Y, median income	+

and less significant:

D, population density	+

There are two somewhat surprising results of the estimation. One is the insignificance of PL in the wage function, suggesting that law enforcement wages are independent of the level of employment of law enforcement personnel, i.e., indicating an infinitely elastic supply of labor. The other is the insignificance of all but the index of frustrated economic ambition, u_4, in the supply of offenses function. This is in contrast with the results of some other studies.

2. Critique. The value of the Phillips and Votey model(s) is its focus on the interaction between crime and law enforcement, and on its emphasis on alternative and complementary public policies for controlling crime, i.e., law enforcement and enhanced economic opportunities (compare with Orsagh's conclusions). The empirical work included in the first model is national in focus; thus the model and policy issues are nationwide. The second model uses California counties for the empirical work, somewhat restricting the urban applicability.

To be of relevance for policy decisions at the local level, the model must include additional dimensions, in particular, consideration of the local public budget and the simultaneous interaction between crime and the local public budget. This is suggested by Phillips and Votey in their second model by focusing on the demand for public law enforcement services and the importance of wages in that decision. However, the actual budget constraint and the impact of crime on fiscal capacity is not included. In addition, while Phillips and Votey suggest the impact of courts and corrections on the deterrence of crime, they do not incorporate this in their analysis. While police activity is primarily a local government responsibility, court and corrections activities and decisions can be state and federal. Yet these activities by other levels of government affect the ability of local police to control crime. This kind of interaction, while suggested by Phillips and Votey, is not developed. In a model with a local government emphasis, the interaction would be a necessary component.

G. The Ehrlich Model

Ehrlich's first major paper on the economics of crime, which established the foundation for his later work focusing on capital punishment, appeared in the Journal of Political Economy in 1973 [6]. This paper builds on earlier work completed for his dissertation. The paper includes development of a theoretical model and empirical estimation of the relationships derived.

1. The Model. Ehrlich was Becker's student; therefore, Ehrlich's work is an extension of the Becker model described first in this review.[4] Here we

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[4]Block and Heineke argue that both Becker and Ehrlich's theoretical formulation, as well as that of Sjoquist, is inadequate since the criminal choice problem is couched in terms of preferences for wealth only, rather than in terms of a multi-attributed structure of preferences. Thus, they argue, the conclusions of Becker, et al., derived from the theoretical construct, are valid only under special conditions. More generally, results of policy parameter shifts are not unambiguous. Prediction of results requires empirical determination of relative magnitudes. See M.K. Block and J.M. Heineke, "A Labor Theoretical Analysis of the Criminal Choice," The American Economic Review, Vol. 65, No. 3, June 1975, pp. 314-325. Their model, while a theoretical contribution, is not reviewed here because it does not include empirical estimates.

repeat some of the comments we made there. Ehrlich builds on the Becker model by developing a theoretical construct which responds to some of the limitations Ehrlich identifies in the Becker framework. Specifically, theoretical limitations addressed by Ehrlich are: 1) the inclusion of only punishment costs in the supply of offenses behavioral relation (except in a very casual way, i.e., the summary term). Ehrlich explicitly considers both costs and gains from legal and illegal activities; 2) the treatment of legal and illegal activities as mutually exclusive choices. Ehrlich argues that the choice to commit criminal acts does not imply that legal sector employment is not also possible. The rational individual will allocate time among legal market activity, illegal market activity, and consumption (which includes leisure); 3) the need to distinguish between the deterrent and preventive (incapacitation) effects of punishment by imprisonment. The distinction is important from a policy perspective since the costs of the latter far exceed those of the former; and, finally 4) the need to analyze the interaction between "offense and defense", i.e., between crime and law enforcement activity. In addition, of course, Ehrlich's paper includes rather extensive empirical work, based on state data for 1940, 1950 and 1960.

Ehrlich's model, based on his theoretical work, is a three equation simultaneous system. In structure, it is similar to the Orsagh model, consisting of a supply of offenses equation, a law enforcement production function, and a public demand for law enforcement function. For purposes of exposition, we recast Ehrlich's equations in symbols common to the other models. Strictly speaking, this glosses over differences between theoretical constructs and between theoretical constructs and their empirical counterparts. However, for our purposes, this is not a serious deficiency and facilitates comparison.

The first equation is a supply of offenses equation:

$$0 = 0\ (p,\ f,\ W_1,\ W_c,\ Un,\ u) \qquad (25)$$

where 0 = offense rate

p = probability of punishment

f = punishment per offense

W_1 = legal gains per time period (measured by % families below one-half the median income -- income inequality)

W_c = illegal gains per time period (measured by median family income)

Un = unemployment rate (probability of unemployment)

u = other factors (environmental) which affect the crime rate

It should be noted that Ehrlich postulates that crime, other things equal, is a positive function of the difference between W_c and W_1, criminal and legal returns per time period. However, he introduces the variables separately in the equation, rather than their difference, to permit the possibility of differing impacts of each on the crime rate (measured in percentage terms). His paper includes a rather lengthy justification of the measures he chooses.

For purposes of estimation, u must be given some measurable identity. Therefore Ehrlich substitutes "environmental" variables for u. In its most expanded form, equation (25) becomes:

$$0 = 0\ (p,\ f,\ W_1,\ W_c,\ Un,\ NW,\ L,\ A) \qquad (26)$$

where NW, L and A are substituted for u.

These are defined as:

NW = percent nonwhite

L = labor force participation rate

A = proportion of young people (males)

The Ehrlich supply of offenses equation, therefore, is similar to that of Sjoquist and shares common variables with some of the other models we have reviewed. However, unlike the single equation models, Ehrlich recognizes the interaction between 0, the crime rate, and p, the probability of punishment (and also admits some other possible interactions but does not incorporate them within this model). He therefore includes a law enforcement production function and a public demand for law enforcement function.

The second equation is a law enforcement production function which is included to translate law enforcement expenditures on police and courts into output, measured by the probability of punishment:

$$p = p\ (E,\ 0,\ z) \qquad (27)$$

where p = probability of punishment

E = law enforcement expenditures

0 = crime rate

z = other factors (environmental) which affect productivity

Law enforcement productivity depends on expenditures on police and courts, the crime rate, and environmental impacts on productivity, such as population size and density. The crime rate is included since, for any given expenditure level, productivity, measured by probability of punishment, is likely to be reduced as the crime rate increases. To achieve the same rate of punishment would require larger numbers of arrests and convictions. This function is similar to Orsagh's equation (9). However, Ehrlich uses expenditures in the function, while Orsagh uses quantity of inputs. It can also be compared with Phillips and Votey's equations (20) and (22).

In the empirical work, z is replaced by a set of environmental variables that are hypothesized to affect law enforcement productivity:

$$p = p\ (E,\ 0,\ P,\ D,\ Pov,\ NW,\ Sc,\ A,\ G) \qquad (28)$$

where P = population

D = population density (scale), measured by percentage of population in Standard Metropolitan Statistical Areas

Pov = percent poverty

NW = percent nonwhite

Sc = average schooling

A = proportion of young people (males)

G = a variable included to measure geographical differences between Northern and Southern states. (The dummy variable technique was used to incorporate this impact)

Finally, Ehrlich includes a function to describe public demand for law enforcement activity:

$$E_t = E\ (Lo,\ 0,\ E_{t-1}) \qquad (29)$$

where E_t = law enforcement expenditures in time t

Lo = potential (average) losses from crime

0 = crime rate

E_{t-1} = law enforcement expenditures in the previous period

The demand for law enforcement, measured by law enforcement expenditures, depends on the potential losses from crime, the crime rate, and law enforcement expenditures in the previous period. [Compare with Orsagh's equation (13)]. The latter term is included to account for costs in adjusting actual expenditures to desired levels. Public expenditures on law enforcement are only partially adjusted toward the desired level in any period. Current actual expenditures therefore, in part, depend on past period, or lagged, expenditures. The "losses" variable is similar in concept to that included in Phillips and Votey's law enforcement input equation (23).

The empirical work focuses on estimation of the relationship between the crime rate and the variables described in equations (25) and (26). This is done for each of the seven Index Crimes, and aggregates of these, using multiple regression analysis of variations in crime rates across U.S. States in 1940, 1950 and 1960. Ehrlich uses various estimation techniques, including single equation and simultaneous system techniques, (the latter using 1960 data only). The results tend to be consistent. Specifically, the following variables were generally found to have a significant impact on the crime rate (the sign of the relationship is indicated to the right):

Variable	All Crimes:	Relationship with Crime Rate
p	the probability of punishment	-
f	average punishment	-
NW	percent nonwhite	+
	Crimes Against Property Only:	
W_1	legal gains per time period, (measured by extent of income inequality)	+
W_c	illegal gains per time period (measured by average income)	+
	Crimes Against Persons Only:	
L	labor force participation rate (ages 14-24)	-

Again, results are consistent with earlier studies. The unexpected sign of the relationship between property crime and legal gains is explained by Ehrlich as perhaps due to its association with urbanization, since the extent of income inequality and the extent of urbanization are highly correlated. What he is measuring, then, is not legal gains, but Pressman and Carol's "scale", which they hypothesize causes crime rates to increase.

The unimportance of the legal and illegal gain variables in the crimes against persons equations is expected, since these variables would not accurately measure gains from this type of crime. The importance, however of the labor force participation rate for crimes against persons, but not crimes against property, is more difficult to comprehend.

Erhlich also estimates the law enforcment production function, equation (28), using a simultaneous system technique. The following variables were found to have a significant impact on law enforcement productivity, measured by the probability of punishment (apprehension and conviction):

Variable	Relationship with Productivity
O, crime rate	-
P, population	-
Pov, percent poverty	+
NW, percent nonwhite	+
Sc, average schooling	+
and less significant:	
A, proportion of young people	-
D, population density	-
G, geographic differences between North and South. The positive sign indicates that, other things equal, productivity is higher in Southern states.	+

The most surprising result is the lack of demonstrated significance of law enforcement expenditures on law enforcement productivity. This may be explained by measurement problems, as well as problems involved in using a production function for all index crimes combined. Expenditures were measured by all expenditures on police activity. This includes non-criminal directed activities, such as traffic control, and excludes expenditures on courts. In addition, if there are differences across states in input prices, the same state expenditures will buy different amounts of inputs and therefore produce different amounts of law enforcement activity. Finally, if there are different production functions for different categories of crime, particularly crimes against persons and crimes against property, and if the "mix" of index crimes between those against persons and those against property varies across states, then estimating a combined, or aggregate production function, will lead to incorrect estimates due to "aggregation bias". This last argument applies to all of the estimated results for the production function, not just the expenditures variable.

The positive relationship between law enforcement productivity and both the extent of poverty and the percent of the population which is nonwhite is a result consistent with that of Orsagh and suggests that individuals with lower incomes spend less on legal counsel and defense, resulting in higher probabilities of punishment.

2. Critique. It is hard to do justice to the Ehrlich model in this summary review since the theoretical accomplishments are not fully credited. However, our purpose is to examine each model for policy relevance, and so we must focus on that aspect. Ehrlich does demonstrate the policy implications of his results by examining the "effectiveness of law enforcement." He does this by combining his results for the supply of offenses equation and the

the production function to link law enforcement expenditures to reductions in crime. His estimates indicate that a one percent increase in direct law enforcement expenditure would result in about a three percent decrease in offenses. This information can then be combined with expenditure data and estimates of social losses from crime to determine whether increased expenditures on crime control are worth it.

The Ehrlich model was estimated using states as the units of observation. There is nothing wrong with this, of course, except that police activity is primarily a local public sector activity. To be policy relevant, then, it would seem to be more useful to use local political jurisdictions as the units of observation and, therefore, to design a model which incorporates the important interactions at the local level. While Ehrlich does include law enforcement expenditures in his model, via a demand function, he does not explicitly include the public sector which finances and makes these expenditure decisions. The impact of crime on the ability of the local public sector to finance crime control would be an important consideration.

H. The Greenwood and Wadycki Model

The Greenwood and Wadycki model is an empirically oriented model [8]. Their major purpose is to develop a simultaneous equations system to describe the interaction between crime rates and public expenditures for police protection. In addition, they address the difficult problem of interpreting reported crime rates as measures of police productivity.

1. The Model. Greenwood and Wadycki begin with specification of an empirical model which they estimate for approximately 200 SMSA's in 1960. There is no theoretical model developed first. The simultaneous system consists of three basic equations: an output equation, which describes output

of the law enforcement sector as a function of inputs; an input equation, which describes quantity of police inputs as a function of police expenditures; and an expenditures equation, which describes police expenditures as a function of crime rates, as well as other factors.

The output equation is really a combination of a production function and a supply of offenses equation. It describes output, measured by the crime rate, as a function of police inputs, and as a function of SMSA characteristics which affect the level of crime, such as legal income opportunities for potential criminals. Greenwood and Wadycki specify two different output functions, one for crimes against property, and one for crimes against persons:

$$O_1 = O_1(PL, Pov, D, NW, Val, G) \quad (30)$$

$$O_2 = O_2(PL, Pov, D, NW, G) \quad (31)$$

where O_1 = SMSA property crime rate

O_2 = SMSA rate of crimes against persons

PL = police labor inputs (per capita full-time equivalents)

Pov = percent poverty

D = population density

NW = percent black

Val = average value of a house (owner-occupied)

G = a variable included to measure geographic differences in output between Northern and Southern SMSA's (dummy variable technique used)

The emphasis in both equations (30) and (31) is on the relationship between police inputs and the crime rate. Greenwood and Wadycki correctly argue that the sign of that relationship as incorporated in their model cannot be determined a priori. They argue that this is because police both prevent and

detect crimes. Other things equal, an increase in detection productivity will increase the reported crime rate (which is the data base used), while an increase in prevention should decrease it. The sign of the relationship between crime rates and police expenditures depends on the relative proportion of crimes reported and unreported, and on the relative efficiency of additional police personnel in detecting vs. preventing crime.

The additional variables in each equation are included as empirical counterparts to Becker's theoretically defined gains and costs of legal vs. illegal activities. A priori expectations of the relationship of each variable to each crime rate are summarized below:

Variable	Expected Relationship with Crime Rate
Pov, percent poverty	+
D, population density (increased density reduces probability of punishment and increases number of crime targets, especially for crimes against persons)	+
NW, actually measured as percent black, not nonwhite (measures reduced legal income opportunities and increased psychic gains from crime)	+
Val, average value of a house (measure of average gain from property crime)	+ (property crime equation only)
G, geographic differences in crime rate due to climate, as well as other factors	+

The input equation specifies the relationship between police expenditures and police labor inputs:

$$PL = PL(E) \quad (32)$$

where PL = police labor inputs

E = local government expenditures for police protection (per capita)

It is expected that police inputs are a positive function of expenditures.

The police expenditure equation, similar to Ehrlich's law enforcement demand function (29), and Orsagh's demand function (13), describes the relationship between police expenditures and the crime rate, as well as other factors:

$$E = E\ (O_1,\ O_2,\ Y,\ Tx) \qquad (33)$$

where E = police expenditures

O_1 = crimes against property (rate)

O_2 = crimes against persons (rate)

Y = average income

Tx = per capita property taxes

It is hypothesized that police expenditures will increase with increases in either of the crime rates, although the extent of the response may differ and therefore the two variables are included separately. In addition, police expenditures will increase with increases in average incomes of households since tastes for police protection may increase with income, and average losses from crime tend to increase with income [compare with Ehrlich's equation (29) which includes average losses and Orsagh's equation (13) which uses Tx for this measure, but also includes Y, and with Phillips and Votey's law enforcement input equation (23) which includes Y as a measure of average loss]. Finally, a local tax base variable (per capita property tax) is included to measure the impact of fiscal capacity, or ability to spend on local public services, on expenditures for police protection. It should be noted, of course, that the property tax is the primary source of revenue to local governments.

The results of three stage least squares estimation of the simultaneous system of equations provide estimates of the relationships which are fairly consistent with expectations. Below we summarize the results by indicating those variables which were found to have a significant impact.

Variable	Sign of Estimated Relationship
Output Equation -- Property Crime [equation (30)]:	
PL, police labor inputs	+
Pov, percent poverty	+
Val, average value of a house	+
G, geographic differences between North and South. The positive sign indicates higher crime rates, other things equal, in Southern SMSA's.	+
and less significant:	
D, population density	-
Output Equation -- Crimes Against Persons [equation (31)]:	
PL, police labor inputs	+
Pov, percent poverty	+
NW, percent black	+
and less significant:	
G, geographic differences between North and South	+
Input Equation [equation (32)]:	
E, police expenditures	+
Expenditures Equation [equation (33)]:	
O_1, crimes against property	+
O_2, crimes against persons	+
Y, average income	+
Tx, per capita property taxes	+

Only two results require comment. First, the positive and highly significant measured relationship between police inputs and both crime rates is interpreted to mean that additional police are more efficient in detecting than preventing crime, and/or that a relatively small percentage of crimes are reported. Thus an increase in number of police results in an increase in measured (reported) crime rates.

The estimated negative relationship between crimes against property and density, although not highly significant, is also explained in terms of the distinction between deterring crimes and detecting them. While an increase in density may reduce the probability of punishment and therefore tend to increase criminal offenses, the increase in offenses may not be reflected in detected or reported crime rates, simply because of the increased anonymity associated with density.

2. Critique. Recognition of the interdependence between crime rates and police expenditures is one accomplishment of the Greenwood and Wadycki model, although by the time their paper was published, other authors, e.g., Phillips and Votey and Ehrlich, had done the same. Perhaps more important is their explicit consideration of the local public sector by including not only police expenditures, as others have done, but also linking those expenditures to the local public sector budget, or local fiscal capacity, as Orsagh did. Their description of the local public sector is incomplete, and their focus on SMSA's rather than political jurisdictions, such as cities, limits the applicability of the model, but nevertheless the public sector is included.

To be adequate, the public sector model should consider intergovernmental transfers and constraints, local tax effort (since equal tax bases yield

different revenues when combined with different tax efforts, or rates) and, the impact of crime on the local tax base via its impact on property value. While Greenwood and Wadycki include property value as one determinant of criminal activity, they do not consider the possibility of a reverse impact -- a reduced property value due to increases in criminal activity.

In addition, McPheters and Stronge [14] (discussed below) criticize Greenwood and Wadycki's interpretation of their estimated positive relationship between police inputs and reported crime rates. Too much is made of the distinction between detection and prevention and the police role in detection. And, as Greenwood and Wadycki admit, detection and prevention are not independent activities, since increased detection presumably leads to increased punishments for crime, which should in turn lead to increased deterrence. Finally, as McPheters and Stronge argue, the Greenwood and Wadycki model does not rest on a theoretical foundation. For this reason their model may not be accurately specified, particularly the output equation which yields the suspicious results. As we pointed out, that equation is a hybrid combination of a supply of offenses equation and a police production function. McPheters and Stronge address this problem in their paper.

I. The McPheters and Stronge Model

The McPheters and Stronge model, published one year after Greenwood and Wadycki, addresses the same basic problem of adequate description of the simultaneous nature of the interaction between crime rates and public expenditures for police protection [14]. However, McPheters and Stronge precede their empirical analysis with a theoretical foundation. They also include in their paper a brief review of the relevant literature.

1. <u>The Model</u>. McPheters and Stronge take issue with the Greenwood and Wadycki model, in particular their specification of the crime function, or output function. Because of this, these researchers disagree with Greenwood and Wadycki's interpretation of their estimated positive relationship between police inputs and reported crime rates. They feel the result is not so much evidence of the importance of the police in detecting crime, but rather the result of a misspecified equation. As we noted above, Greenwood and Wadycki's output function is really a combination of a supply of offenses equation and a police production function. Because of this mixing of behavioral relations within one equation, the results are difficult to interpret. The supply of offenses equation cannot be disentangled from the production function.

McPheters and Stronge specify a two equation model. They begin with a police expenditure equation:

$$E = E(0, B, x) \qquad (34)$$

where E = local government expenditures on police protection, per capita

0 = the crime rate

B = the municipal budget constraint

x = a portmanteau variable which reflects the community's taste for police protection [This variable is in part proxied by Greenwood and Wadycki by including average income. See equation (33)].

Given the community budget constraint and tastes for protection, the relationship between offenses and expenditures for police is expected to be positive.

The supply of offenses equation, which they call a crime reaction function, is represented by:

$$0 = 0(E, u) \qquad (35)$$

where 0 = the crime rate

E = police expenditures

u = a set of environmental and taste variables which affect the amount of crime

Given u, the relationship between police expenditures and the crime rate is expected to be negative.

Thus the expected relationship between crime and police expenditures is positive in equation (34), and negative in equation (35). In empirical work, when one collects data on crime rates and associated police expenditures for different years, or for different cities, it is impossible to distinguish between a measurement of the relationship in (34), from that in (35), unless other factors in each equation are properly accounted for, and unless at least some of those other factors are different between the two equations. This typical econometric problem is referred to as the "identification problem". (This problem is discussed in more detail in Appendix A).

McPheters and Stronge estimate their model using 1970 data for the 43 largest central cities in the U.S. Their data base is therefore consistent with a focus on policy since the units of observation are political entities with primary responsibility for provision of police protection.

In order to estimate the model, the catch-all variables need to be specified. Here, McPheters and Stronge make an additional contribution to research in this area. Rather than including a small number of selected environmental variables to replace u in equation (35), as other authors have done (with the exception of Phillips and Votey [21]), they argue that a large number of economic and demographic characteristics of central cities are likely to have an important influence on crime rates. Therefore, all should be included. However, since many of these characteristics are highly correlated, to use all of them in equation (35) would cause another econometric problem - "multicollinearity". When this happens, the influence of one variable, or characteristic, cannot be adequately separated from the influence of others with which it is correlated, so that empirical results are misleading and difficult to interpret. To avoid this, the authors use a technique called principal components analysis, whereby they are able to reduce the information contained in the larger data set to a smaller number of uncorrelated "index" variables which describe the basic characteristics of the central cities observed. In a sense, they improve upon Orsagh's efforts to combine variables or information into single indices. Principal components analysis is also used by Phillips and Votey in a model which is described earlier in the text, but which appeared later in the literature [21].

The larger data set with which they begin contains many of the variables used by other researchers cited above, and elsewhere. The 21 variables include measures of income, poverty, unemployment, population density and change, education, age and racial mix, housing characteristics and public expenditures. These 21 variables were reduced to six indices which are interpreted as measures of: u_6, central city decay; u_7, central city affluence; u_8, minority presence, u_9, education; u_{10}, housing quality; and u_{11}, youth presence. The components are then substituted for u in equation (35) to obtain estimates of the crime reaction function.

Finally, McPheters and Stronge argue that the amount of crime in any period is a function, not of the current values of police expenditures and

crime "causes" (the indices), but of their lagged values, or values in previous periods. This is because the level of crime depends on perceived police expenditures, which are a function of previous actual levels. In addition, the level of crime gradually adjusts to its causes and therefore depends on past values of these "causes", or indices, not on current values.

In order to incorporate the influence of past values, the authors argue that crime is a distributed lag function of police expenditures and the six indices. By applying what is called a "Koyck transformation" to their equation, the distributed lags are replaced by the lagged value of the dependent variable, the crime rate. Thus, with this adjustment, the empirical counterpart to equation (35) becomes:

$$O_t = O(E, u_6, u_7, u_8, u_9, u_{10}, u_{11}, O_{t-1}) \quad (36)$$

where O_t = crime rate in the current period

E = current level of police expenditures per capita

$u_6, \ldots, u_{11}$ = current values for each of the six indices of central city characteristics

O_{t-1} = crime rate in the previous period

Equation (36) was then estimated. The following variables were found to have a significant impact on the crime rate:

Variable	Relationship with Crime Rate
E, police expenditures	-
u_6, central city decay	+
u_7, central city affluence	+
u_9, education	+
u_{11}, youth presence	+
O_{t-1}, lagged crime rate	+

and less significant:

Variable	Relationship with Crime Rate
u_{10}, housing quality	+ (larger values of the index mean lower housing quality)

The significant negative impact of police expenditures on crime is, of course, what McPheters and Stronge had hoped to find. Their results are consistent with their expectations that "when a sufficient number of basic causal variables appear in the crime function, the true deterrent influence of police expenditures on criminality become evident."

The positive sign of the relationship between the crime rate and both urban decay and youth presence fits with expectations. The positive influence of affluence and education is explained by McPheters and Stronge as due to these components measuring potential gains to crime. The lagged crime rate has the expected impact on current crime rates -- a positive relationship. (The estimated coefficient of the lagged crime rate variable is less than one, a condition necessary for the system to be stable, i.e., not lead to explosive increases in the crime rate).

While the housing quality index has a less significant measured impact on crime, the impact is as expected. Increases in the index, which measure decreases in housing quality, lead to increases in crime, other things being equal. Finally, the insignificance of the minority presence index is an interesting contrast to most other empirical studies which find a positive relationship between crime and minority percentages. This result suggests that when all other factors are accounted for, there is no independent influence of minority presence on crime rates.

The police expenditures equation, equation (34), was also estimated, without including a taste variable:

$$E = E\ (O,B) \qquad (37)$$

where E = police expenditures, per capita

O = crime rate

B = municipal budget constraint, measured by municipal revenues per capita

Both variables were hypothesized to have a positive impact on expenditures. The estimated results confirm these expectations.

2. Critique. The McPheters and Stronge research combines a theoretical foundation with rather sophisticated statistical analysis. Their paper also includes an interesting application of the results of their model estimation to urban policy questions.

One potentially important result is their finding that the municipal budget has a relatively weak impact on police expenditures and on crime rates, suggesting that: 1) the municipal budget is less of a constraint on police expenditures than on other types of spending, perhaps because of the importance of the amount of crime as a determinant of spending; and 2) the deterrent effect of law enforcement expenditures is rather small. These two findings would appear to be inconsistent, or imply that municipal police budget allocation decisions are not necessarily optimal. What is needed, or course, to make this determination, are measures of the cost of police protection and the benefits derived from that protection. For this to be accomplished, it is necessary for all interactions between crime and police expenditures to be incorporated within the model. In particular, the impact of crime on municipal property values, and thereby on municipal budget constraints, should be examined. In addition, to the extent that other levels of government do or should influence municipal budget decisions, intergovernmental links in the process should be recognized.

J. The Wilson and Boland Model

The Wilson and Boland Model appeared in a special edition of Law and Society Review which was devoted to papers on criminal justice [26]. While Wilson and Boland focus on the crime of robbery, their model is of general interest, partly because they consider political variables which are largely ignored in the models reviewed here. Policy relevance is emphasized. The research was supported by a grant from the Law Enforcement Assistance Administration to the Urban Institute.

1. The Model. Wilson and Boland are interested in modelling and estimating the impact of the police on crime, in particular, the impact of the risk of arrest on robbery rates. They argue that there are two problems which must be addressed in any examination of this type. First, is the simultaneous nature of the relationship between crime and crime control (here measured by arrest rates). Many of the other models reviewed here address the same problem.

Secondly, police practices may have important impacts on crime rates, independent of the impact of the number of police, and independent of the impact of police on arrest rates. Police practices, or kinds of activity, may affect the crime rate, and affect it only indirectly, or not at all, by affecting the probability of arrest. In addition, these activities of police may be more important than numbers of police. Finally, police practices or patrol strategies may be affected by bureaucratic decisions as much as by police budgets.

In order to incorporate this "police activity effect" in their model, Wilson and Boland require a measure of different types of strategies. They make a distinction between two extremes -- an "aggressive" strategy, and a "passive" one. As a proxy measure for the existence of an aggressive strategy, they use the number of citations for moving traffic violations issued per sworn officer. Note that this variable could also measure public demand for non-

criminal activities of police, similar to Orsagh's traffic supervision variable in equation (15).

Their model is a four-equation simultaneous system. The first equation is a supply of offenses, or crime rate equation:

$$O = O\ (AR, A, NW, Un, D) \qquad (38)$$

where O = crime rate (robbery)

AR = probability of arrest (similar to Becker's probability of punishment, p)

A = proportion of young people (males)

NW = percent nonwhite

Un = unemployment rate

D = population density

This equation is similar to many others we have reviewed.

The police output equation, referred to as the arrest productivity equation, is represented by:

$$AR = AR\ (AP, O/PU, NW) \qquad (39)$$

where AR = probability of arrest

AP = aggressive patrol strategy

O/PU = total index crimes per patrol unit

NW = percent nonwhite

Output, as measured by the arrest probability, depends on the level of police inputs relative to the crime problem (O/PU), an environmental variable that may affect police productivity (NW), and the type of patrol strategy (AP). It is inclusion of the patrol strategy variable which distinguishes this police output equation from others, e.g., Orsagh's equation (12), Phillips and Votey's equations (18) and (22), or Ehrlich's equation (28).

By including the patrol strategy variable in the model in this way, Wilson and Boland are forced to make two assumptions. First, and perhaps very plausibly, they assume that police strategy is not dependent on the crime rate and therefore there is no need for a function to explain police strategy as a function of crime. They argue that strategy selection depends on the political arrangements within which police decisions are made. Secondly, they must assume that police strategy affects crime only indirectly, through its impact on the probability of arrest. To permit a direct impact on crime requires that this variable also appear in the supply of offenses equation, causing an identification problem. The latter assumption, however, is inconsistent with their own description of the importance of police strategy in controlling crime.

The third equation of the model is a police deployment equation which is included to explain the number of patrol units on the street:

$$PU = PU\ (PL,\ TO,\ D,\ P) \qquad (40)$$

where PU = patrol units on the street, per capita

PL = police labor inputs (number of sworn officers per capita)

TO = proportion of officers assigned to two-officer rather than one-officer cars

D = density, measured by housing density

P = population

Inclusion of a police deployment equation is unusual, based on the studies we have reviewed here.

The final equation of the model is a police input equation:

$$PL = PL\ (0_1,\ 0_2,\ Tx,\ W,\ G) \qquad (41)$$

where PL = police labor inputs (number of sworn officers per capita)

0_1 = property crime rate

0_2 = rate of crimes against persons

Tx = equalized property tax base, per capita

W = cost of hiring additional manpower (measured by starting salary of sworn officers)

G = a variable included to measure geographic differences between the Northeast and other cities in expenditures on municipal services (dummy variable technique used)

This input equation can be compared with Orsagh's equation (13) and a combination of Greenwood and Wadycki's input equation (32) and expenditure equation (33). Like Phillips and Votey [equation (23)], Wilson and Boland recognize the possible importance of input prices on the hiring decision, and unlike the others, permit geographic differences in expenditure and input patterns. Since this equation is a combination input-expenditure function, it should also be compared with Ehrlich's expenditure equation (29) and McPheters and Stronge's expenditure equation (37).

The four equations are estimated using 1975 data from the 35 largest cities in the U.S. Thus, like McPheters and Stronge, the units of observation are political entities with primary responsibility for police protection. Therefore the results are policy relevant.

The statistical results of estimation of equations (38) - (41) are summarized below. Those variables found to have a statistically significant influence in each equation are:

Variable	Sign of Estimated Relationship
Supply of Offenses Equation [equation (38)]:	
AR, probability of arrest	-
NW, percent nonwhite	+
D, population density	+
and less significant:	
A, proportion young people (males)	-
Un, unemployment rate	+
Police Output Equation [equation (39)]:	
AP, aggressive patrol strategy	+
O/PU, total index crimes per patrol unit	-
Police Deployment Equation [equation (40)]:	
PL, police labor inputs	+
TO, proportion of officers assigned to two-officer cars	-
P, population	-
Police Input Equation [equation (41)]:	
O_2, crimes against persons	+
Tx, per capita tax base	+

For the most part the results are consistent with expectations. Controlling for environmental factors, the crime rate is negatively related to the probability of arrest. This, in turn, is a positive function of aggressive patrol strategies, and a negative function of workload. The significant negative estimated relationship between arrest probabilities and work-

load (crimes per patrol unit) is in contrast to some other results, e.g., those of Greenwood and Wadycki, but consistent with Phillips and Votey's equation (22). Wilson and Boland feel their result is due to better measurement of police inputs, i.e., use of number of patrol units rather than total number of police. The number of patrol units on the street depends on the amount of labor, the decision to deploy two officer cars, and city population size. The number of police labor inputs depends on the rate of crimes against persons (but not against property) and the city tax base, or fiscal capacity. Unlike Phillips and Votey [equation (23)], Wilson and Boland find that the wage, or the cost of hiring additional police labor inputs, is insignificant.

Wilson and Boland go on to examine city characteristics that contribute to an aggressive police patrol strategy. They find that the political culture, measured by the presence of a professional city manager, encourages an aggressive type strategy.

2. Critique. The Wilson and Boland paper is interesting because it considers the political realities of law enforcement activity, a perspective missing from the economic models. By focusing on city decision making, and using an appropriate data base, Wilson and Boland provide an interesting contribution for those interested in urban planning and urban policy with respect to crime control.

From an economic perspective, however, the model lacks sufficient theoretical development. For the most part, justification of variables included, and *a priori* expectations of relationships between variables are not specified. In addition, the description of the urban public sector, and the interaction between that sector and crime is inadequate. The impact of crime on the fiscal capacity of the city via a reduction in property values, is a possibility which is overlooked. We turn now to a model which recognizes this potential complication.

K. The Hellman and Naroff Model

The Hellman and Naroff model, the most recent of the efforts reviewed here, began as a single equation derived from traditional models of urban land use [10]. Thus the model comes from a different perspective than the others described, and has a different emphasis. It comes from the realm of urban economics, and appropriately focuses on urban issues and policy, including the interactions among crime, property values and land use patterns.

1. The Model. The Hellman and Naroff model begins with a focus on urban property values and the impact that crime has on property values. They argue that this is an important issue since property values largely determine the tax base of cities, and therefore the revenues available for financing public services, including crime control. Thus, initially, the model consists of a single equation -- a property value equation:

$$Val = Val\ (O,\ Y,\ Di) \qquad (42)$$

where Val = average value of a house

O = crime rate

Y = average income

Di = distance from Central Business District (CBD)

Average property value, Val, other things equal, is expected to decrease in areas where crime rates are relatively high. This is the relationship of central concern in the Hellman and Naroff model. The other two variables included in equation (42) are standard components of a property value equation. Other things equal, income is expected to have a positive impact on property values, while distance from the CBD should lower values to compensate for increased transportation costs. It is recognition of the impact

of crime on property values via incorporation of a property value equation, which is Hellman and Naroff's contribution.

Equation (42) is estimated using 1970 data on housing values for census tracts in Boston, Massachusetts. The following variables are found to be significantly associated with property values (measured by median value of owner-occupied property):

Variable	Sign of Estimated Relationship
O, crime rate	-
Y, average income	+
Di, distance from CBD	+

The significant negative impact of crime on average property values within a census tract is, of course, the result that Hellman and Naroff were looking for. The somewhat unexpected positive impact of distance on property values is explained by the authors as resulting from lack of control for characteristics such as plot size and age of the housing unit. If housing units located further from the CBD are newer and on larger lots, then housing value may increase with distance, in spite of the effect of transportation costs.

Hellman and Naroff go on to calculate the property tax revenues lost to the City of Boston due to crime, based on their estimates of the impact of crime on property values.[5] Thus the model is shown to have practical policy significance. However, as it stands, the model is incomplete. An obvious

[5] A similar single equation model of the impact of crime on housing values is esimated by Gray and Joelson with similar results. See C.M. Gray and M.R. Joelson, "Neighborhood Crime and the Demand for Central City Housing," in The Costs of Crime, C.M. Gray, ed., Sage Publications (Beverly Hills, CA, 1979). Their analysis is performed on census tracts in Minneapolis for 1970.

shortcoming is lack of an explanation of the crime rate, itself, i.e., the need to include a supply of offenses equation in the model. This is done by Hellman and Naroff in a later paper [17].

A supply of offenses, or crime generation function is described by:

$$O = O\ (Val,\ D,\ NW,\ Un,\ Q) \qquad (43)$$

where O = crime rate

Val = average value of a house

D = density

NW = percent black

Un = unemployment rate

Q = index of housing quality

This equation is different from all of the others reviewed here, primarily because it does not include a law enforcement variable, measured either as the probability of punishment, the severity of punishment, or the number of law enforcement inputs. The reason for this is the data base used by Hellman and Naroff. Since they are working with census tracts, the argument is that these variables, at least the first two, are constant throughout the city. While police inputs are not equal in all tracts, they are very mobile among them.

The other difference is the emphasis on housing, both the value, Val, included as a measure of potential gain from crime [similar to that of Greenwood and Wadycki's equation (30)], and the quality of housing, [similar to the housing quality factor included in McPheters and Stronge's equation (36)]. The other variables included in equation (43) have been used in several other models.

The property value equation (42) is expanded by replacing average income, Y, with income and housing characteristics:

$$Val = Val\ (O,\ Di,\ NW,\ Cr,\ Un) \qquad (44)$$

where Val = average value of a house

O = crime rate

Di = distance from the CBD

NW = percent black

Cr = overcrowdedness

Un = unemployment rate

Equations (43) and (44) are estimated using a simultaneous systems technique (three stage least squares). Those variables found to have a statistically significant influence in each equation are:

Variable	Sign of Estimated Relationship
Supply of Offenses Equation [equation (43)]:	
NW, percent black	+
and less significant:	
D, density	-
Property Value Equation [equation (44)]:	
O, crime rate	-
Cr, overcrowdedness	-
and less significant:	
Di, distance from CBD	+

The negative impact of density on crime rates is similar to that found by Greenwood and Wadycki, and perhaps is explained in the same way. The argument is that while an increase in density may reduce the probability of punishment and therefore tend to increase criminal offenses, the increase in offenses is not reflected in detected or reported crime rates because of the increased anonymity associated with density.

The lack of performance of the rest of the variables in the supply of offenses equation is somewhat disappointing but may be explained by the data base. To the extent that both criminals and victims are mobile among census tracts, it may be more difficult to associate crime rates within tracts to tract characteristics than, e.g., to associate overall city crime rates with city characteristics.

The results of estimating property value equation (44) are similar to those of equation (42). The significant negative impact of the crime rate in the two-equation, simultaneous system is the most important result. The lack of significance of some of the variables may be explained by multicollinearity, a problem which could be avoided using a technique similar to that employed by McPheters and Stronge or Phillips and Votey.

2. Critique. The Hellman and Naroff model is unique in its emphasis on the impact of crime on urban property values and land use patterns. For the most part, this has been ignored by other researchers. Katzman recognizes the impact of the land use pattern in an urban area on opportunities for crime, but does not consider the reverse impact, i.e., the effect crime has on property values. Nor does he attempt empirical estimation of his hypothesized impact. Other researchers, e.g., Greenwood and Wadycki, and McPheters and Stronge have included property value or housing characteristics in their supply of offense equations. Several authors -- Orsagh, Greenwood and Wadycki, McPheters and Stronge, and Wilson and Boland -- have included a tax base or fiscal capacity constraint in their law enforcement expenditure, or input equations. But only Hellman and Naroff have considered both sides of the relationship, i.e., the simultaneous relationship between crime and property values.

Nevertheless, the Hellman and Naroff model needs refinement. Use of a different data base would seem appropriate. While focusing on census tracts as units of observation may be appropriate in a study of urban property values, when crime is added to the model as an endogenous variable, i.e., as a variable which is to be explained by the model, rather than be taken as given or pre-determined, then the focus should probably change. For one, as we have already mentioned, crime, criminals and victims are very mobile among census tracts, so it is difficult to "explain" tract crime rates by looking at tract characteristics. Secondly, in order to incorporate the full interactions among crime, property values and the local public sector, including public crime control, it is necessary to have a data base which permits differences in law enforcement variables such as the probability of punishment and severity of punishment, as well as differences in other public sector characteristics, such as tax revenues. (It should be noted that Hellman and Naroff do discuss incorporation of additional functions within their model, but do not estimate them due to their data base.) Thus use of large central cities as units of observation would be an improvement which would permit simultaneous examination of the impact of crime on property values, city revenues and police expenditures, the crime generation process, and the law enforcement production process.

This completes our review of previous modelling efforts. In the following section we summarize the review, highlight the contributions and shortcomings identified in the various models, and describe, in general terms, a model which incorporates all of the significant interactions among criminal activity, the criminal justice system, urban property values, and urban fiscal capacity.

SECTION II. SUMMARY AND DEVELOPMENT OF PREVIOUS MODELS

Section I contains a detailed review and description of prototypes of previous related model building efforts. Each model was examined and critiqued in terms of both theoretical and technical qualities, as well as policy relevance. In this section, we first summarize these modelling efforts, recognize the significant developments, and then identify the major gaps or shortcomings in the modelling effort as a whole. Based on this, a model which incorporates the suggested revisions and adequately describes the crime rate/ property value/revenue feedback is presented. In this section the model is presented as a verbal one. Section III contains an econometric version of the same general model.

A. Summary of Models

Tables 2-1 and 2-2 summarize the eleven models reviewed which contain empirical estimates of equations. In Table 2-1, the empirical models are listed by author(s), in the order in which they are discussed in Section I, i.e., approximately chronologically. Column one identifies the model. Column two describes the types of equations included. Column three lists the variables which are considered, or tested for significance in each equation. The variables are listed in alphabetical order to facilitate comparison from equation to equation, and model to model. Again, to facilitate comparison of results, the empirical counterparts to variables are listed. Therefore, different theoretical constructs, if measured with the same variable, show up the same in the table. Differences in measurement of variables which are basically the same are also glossed over; the same variable symbol is used. In a few instances, somewhat different equations were estimated for different crimes, e.g., crimes against persons vs. crimes against property. These, too, are glossed over and summarized. Finally, a definition of variable symobls in contained in Table 2-3.

CONTINUED

1 OF 2

TABLE 2-1.

SUMMARY OF EMPIRICAL MODELS REVIEWED, BY MODEL

MODEL	TYPE OF EQUATION(S) (DEPENDENT VARIABLE)	INDEPENDENT VARIABLES CONSIDERED	VARIABLES SIGNIFICANT (SIGN)	DATA BASE (SAMPLE SIZE)
Orsagh [18]	Supply of Offenses (O)	A, Ch, Ec, p, NW, S	NW (+), S (+)	Large cities and counties, California 1960 (55)
	Production Function (p, probability of sentence)	A, NW, O, PL, Pov, Sz	NW (+), PL (+), Pov (+)	
	Input Function (PL)	Gs, O, Tx, Y	Gs (+), O (+), Tx (+)	
Pressman and Carol [23]	Supply of Offenses (O)	Ch*, Cl, D, Ec, NW, Pl, Pov, Sc	Ch (+), NW (+)	SMSA's 1965 (95)
Allison [1]	Supply of Offenses (O)	A, Ch, D, Di, E, Ed, M, NW, P Pk, PL, Sc, Un, Y	A (+), Di (–), M (+) Pk (–), Sc (+), Un (+)	Municipalities, Chicago area, 1960 (Not reported)
Sjoquist [24]	Supply of Offenses (O)	D, f, NW, p, P, Pov, RS, Sc, Un, Y	f (–), NW (+), p (–), P (+), Sc (+), Un (+)	Municipalities, 1968 (53)
Phillips and Votey [20]	Supply of Offenses (O)	p, t, Un·L	p (–), t (+), Un·L (–)†	Not reported
	Production Function (p, clearance rate)	E, O, t	E (+), O (–), t (+)†	
Phillips and Votey [21]	Supply of Offenses (O)	f, p, u_1, u_2, u_3, u_4, u_5	f (–), p (–), u_4 (+)	Counties, California 1966 (50)
	Production Function (p, conviction rate)	O, PL	O (–), PL (+)	
	Input Function (PL)	CM**, O, W, Y**	O (+), W (–)	
	Wage Function (W)	D, PL, Y	D (+), Y (+)	

TABLE 2-1.

(continued)

MODEL	TYPE OF EQUATION(S) (DEPENDENT VARIABLE)	INDEPENDENT VARIABLES CONSIDERED	VARIABLES SIGNIFICANT (SIGN)	DATA BASE (SAMPLE SIZE)
Ehrlich [6]	Supply of Offenses (O)	A, f, L, NW, p, Pov, Un, Y	f(-), L(-), NW(+), p(-), Pov(+), Y(+)	States, 1940, 1950 1960 (36-47)
	Production Function (p, arrest and conviction rate)	A, D, E, G, NW, O, P, Pov, Sc	A(-), D(-), G(+), NW(+), O(-), P(-), Pov(+), Sc(+)	
	Expenditures Function (E)	E_{t-1}, Lo, O	Not estimated	
Greenwood and Wadycki [8]	Supply of Offenses (O)	D, G, NW, PL, Pov, Val	D(-), G(+), NW(+), PL(+) Pov(+), Val(+)	SMSA's, 1960 (199)
	Input Function (PL)	E	E(+)	
	Expenditures Function (E)	O, Tx, Y	O(+), Tx(+), Y(+)	
McPheters and Stronge [14]	Supply of Offenses (O)	E, O_{t-1}, u_6, u_7, u_8, u_9, u_{10}, u_{11}	E(-), O_{t-1}(+), u_6(+), u_7(+) u_9(+), u_{10}(+), u_{11}(+)	Largest cities, 1970 (43)
	Expenditures Function (E)	B, O	B(+), O(+)	
Wilson and Boland [26]	Supply of Offenses (O)	A, D, NW, p, Un	A(-), D(+), NW(+), p(-), Un(+)	Largest cities, 1975 (35)
	Production Function (p, arrest rate)	AP, NW, O/PU	AP(+), O/PU(-)	
	Deployment Function (PU)	D, P, PL, TO	P(-), PL(+), TO(-)	
	Input Function (PL)	G, O, Tx, W	O(+), Tx(+)	
Hellman and Naroff [17, 10]	Supply of Offenses (O)	D, NW, Q, Un, Val	D(-), NW(+)	Census tracts, Boston 1970 (147)
	Prop. Value Function (1) (Val)	Cr, Di, NW, O, Un	Cr(-), Di(+), O(-)	
	Prop. Value Function (2) (Val)	Di, O, Y	Di(+), O(-), Y(+)	

* = Could also be interpreted as S, an index of urbanization

† = Significance of results not reported

** = Measure of Lo, average loss from crime

Column four indicates those variables which were found to have a significant impact in each of the equations. If an equation was estimated for different types of crime, or using different statistical techniques so that there is more than one set of results, a variable is reported as significant even if it was not found to be so in all cases. The sign of the estimated relationship between each variable and the dependent variable of the equation is indicated in parentheses. In a very few cases, the signs do not make any sense or cannot be interpreted without reference to the detailed model and a complete definition of the variable, e.g., "G". Finally, the last column indicates the data base used in the empirical work and the size of the sample.

In Table 2-2, the empirical models are listed by types of equation, indicated in column one. The second column lists each model which contains that type of equation. Columns three and four indicate the variables considered by each researcher(s) in each equation, and those variables found significant. Table 2-2 facilitates comparison of particular functions, where Table 2-1 permits comparison of models.

From the tables it is fairly easy to trace and compare the development of the models. With the exception of Orsagh, the earlier models are single equation types, focusing on a supply of offenses, or crime generation function. This gave way to two, three or four equation simultaneous systems.

TABLE 2-2.

SUMMARY OF EMPIRICAL MODELS REVIEWED, BY TYPE OF EQUATION

TYPE OF EQUATION (DEPENDENT VARIABLE)	MODEL INCORPORATING	VARIABLES CONSIDERED	VARIABLES SIGNIFICANT (SIGN)
Supply of Offenses (O)	Orsagh [18]	A, Ch, Ec, p, NW, S	NW(+), S(+)
	Pressman and Carol [23]	Ch*, Cl, D, Ec, NW, PL, Pov, Sc	Ch(+), NW(+)
	Allison [1]	A, Ch, D, Di, E, Ed, M, NW, P, Pk, PL, Sc, Un, Y	A(+), Di(-), M(+), Pk(-), Sc(+) Un(+)
	Sjoquist [24]	D, f, NW, p, P, Pov, RS, Sc, Un, Y	f(-), NW(+), p(-), P(+), Sc(+) Un(+)
	Phillips and Votey [20]	p, t, Un·L	p(-), t(+), Un·L(-)†
	Phillips and Votey [21]	f, p, u_1, u_2, u_3, u_4, u_5	f(-), p(-), u_4(+)
	Ehrlich [6]	A, f, L, NW, p, Pov, Un, Y	f(-), L(-), NW(+), p(-), Pov(+), Y(+)
	Greenwood and Wadycki [8]	D, G, NW, PL, Pov, Val	D(-), G(+), NW(+), PL(+), Pov(+) Val(+)
	McPheters and Stronge [14]	E, O_{t-1}, u_6, u_7, u_8, u_9, u_{10}, u_{11}	E(-), O_{t-1}(+), u_6(+), u_7(+), u_9(+), u_{10}(+), u_{11}(+)
	Wilson and Boland [26]	A, D, NW, p, Un	A(-), D(+), NW(+), p(-), Un(+)
	Hellman and Naroff [17]	D, NW, Q, Un, Val	D(-), NW(+)

TABLE 2-2.

(continued)

TYPE OF EQUATION (DEPENDENT VARIABLE)	MODEL INCORPORATING	VARIABLES CONSIDERED	VARIABLES SIGNIFICANT (SIGN)
Production Function (p)	Orsagh [18]	A, NW, O, PL, Pov, Sz	NW(+), PL(+), Pov(+)
	Phillips and Votey [20]	E, O, t	E(+), O(-), t(+)†
	Phillips and Votey [21]	O, PL	O(-), PL(+)
	Ehrlich [6]	A, D, E, G, NW, O, P, Pov, Sc	A(-), D(-), G(+), NW(+), O(-), P(-), Pov(+), Sc(+)
	Wilson and Boland [26]	AP, NW, O/PU	AP(+), O/PU(-)
Input Function (PL)	Orsagh [18]	Gs, O, Tx, Y	Gs(+), O(+), Tx(+)
	Phillips and Votey [21]	CM**, O, W, Y**	O(+), W(-)
	Greenwood and Wadycki [8]	E	E(+)
	Wilson and Boland [26]	G, O, Tx, W	O(+), Tx(+)
Expenditures Function (E)	Ehrlich [6]	E_{t-1}, Lo, O	Not estimated
	Greenwood and Wadycki [8]	O, Tx, Y	O(+), Tx(+), Y(+)

TABLE 2-2.

(continued)

TYPE OF EQUATION (DEPENDENT VARIABLE)	MODEL INCORPORATING	VARIABLES CONSIDERED	VARIABLES SIGNIFICANT (SIGN)
Expenditures Function (E) (continued)	McPheters and Stronge [14]	B, O	B(+), O(+)
Wages Function (W)	Phillips and Votey [21]	D, PL, Y	D(+), Y(+)
Deployment Function (PU)	Wilson and Boland [26]	D, P, PL, TO	P(-), PL(+), TO(-)
Property Value Function (Val)	Hellman and Naroff [10, 17]	(1) Di, O, Y (2) Cr, Di, NW, O, Un	Di(+), O(-), Y(+) Cr(-), Di(+), O(-)

* = Could also be interpreted as S, an index of urbanization

† = Significance of results not reported

** = Measure of Lo, average loss from crime

TABLE 2-3. DEFINITION OF VARIABLE SYMBOLS

A = age mix of the population (measured somewhat differently in different models, generally a presence of youth variable).

AP = aggressive patrol strategy (measured by citations for moving traffic violations).

B = municipal revenues per capita.

Ch = change (measured in different ways which focus individually or in combination on population stability and shifts in location and composition).

Cl = climate.

CM = crime mix (ratio of nonviolent to violent crime).

Cr = overcrowdedness (housing).

D = population density.

Di = distance from central city.

E = law enforcement expenditures per capita.

Ec = economic well-being (measured variously as a combination of income, employment, health and educational characteristics).

Ed = expenditures on education.

f = severity of punishment (measured by average sentence served, fraction of convictions resulting in severe committments, and fraction of felony sentences resulting in probation with jail).

G = geographic differences (which may include, but not be restricted to differences in climate, Cl).

Gs = gasoline sales per capita (intended as a proxy for demand for police for traffic control).

L = labor force participation rate (in some models, measured for only certain population groups).

TABLE 2-3. (Continued)

Lo = potential losses from crime (no empirical counterpart given).

M = proportion males.

NW = racial mix (measured as percentage of black or percentage nonwhite).

O = crime rate (measured for total index crimes, individual index crimes, or combinations of index crimes).

p = probability of punishment (measured by probability of arrest, probability of conviction, probability of conviction/given arrest, probability of serving a sentence of at least six months, and the clearance rate).

P = population.

Pk = expenditures on parks and recreation.

PL = police labor inputs.

Pov = percent poverty.

PU = police patrol units.

Q = index of housing quality.

RS = retail sales per establishment.

S = index of urbanization.

Sc = educational level of the population.

Sz = community size.

t = time.

TO = proportion of two-officer, rather than one-officer police patrol cars.

Tx = property taxes per capita (similar to B).

Un = unemployment rate (in some models, measured only for certain population groups).

Val = average value of a house.

W = wage (salary) for law enforcement personnel.

Y = average income.

TABLE 2-3. (Continued)

Each of the following variables is an index constructed using principal components analysis. As such, each index may be associated with one or more of the variables listed above. The first five are indices for counties in California, the next six are for U.S. cities.

Counties (California):

u_1 = urbanness

u_2 = poverty

u_3 = presence of disadvantaged youth

u_4 = index of frustrated economic ambition

u_5 = change or instability

Cities (U.S.):

u_6 = central city decay

u_7 = central city affluence

u_8 = minority presence

u_9 = education

u_{10} = housing quality (larger values indicate worse quality)

u_{11} = youth presence

B. Model Development

The chronological listing of the models in Table 2-1 summarizes the development of the model building efforts over the past approximately ten years, with the exception of the three earliest models which do not contain empirical estimates of behavioral functions, i.e., Becker [2], Katzman [13], and Blumstein and Larson [3].

The Becker model, which we dismiss here because it contains no empirical estimates, actually is the basis for much of the study of the economics of crime. In addition, Becker develops a simultaneous system of equations in which the interaction between offense and defense is implied, if not empirically estimated. While the Becker model lacks an empirical or policy emphasis because of its abstract nature, the theoretical construct nevertheless laid the foundation for additional theoretical and empirical work analyzing the relationships among crime, law enforcement, and public revenues.

The Katzman model is also significant. It focuses on the resource allocation or economic choices which society must make in deterring crime. Katzman's model is presented as a schematic illustrating the complex interactions among the activities of the police, the public and criminals in an urban area. While again no empirical estimates of the relationships are presented, the detail and focus of the modelled interactions can be contrasted with those of Becker; Katzman is microanalysis. As such, real policy options are illustrated, including, but not limited to police input and activity decisions.

The Blumstein and Larson model comes from the field of operations research. It contains empirical estimates, but not of the type of behavioral relations contained in the other models and therefore is not really comparable. It is

included here, however, because the model describes interactions among the various components of the criminal justice system -- police, prosecution, courts, corrections -- and criminal activity. For the most part, the other models reviewed here focus only on law enforcement, or police activities.

The Orsagh model begins the list of those with an empirical element, if not focus. It represents the first empirically estimated, simultaneous equation model of crime and law enforcement. It recognizes: the impact which the crime rate, among other things, may have on the public's demand for police; the impact which both the number of police and the crime rate may have on police output, or criminal sanctions; and, includes the potential impact of criminal sanctions on the amount of crimes committed. The model also recognizes the constraint of community fiscal capacity on its ability to provide police inputs, and, therefore, law enforcement.

Listed after Orsagh on Table 2-1 are three examples of single equation models which contain only a supply of offenses function. While they represent interesting variations on a theme, each of these models fails to recognize the simultaneous nature of the relationship between crime and law enforcement activity. While they attempt to measure the impact of law enforcement on crime, they do not consider the reverse effect.

The Phillips and Votey model (particularly the second one reviewed) is similar to that of Orsagh in that it recognizes the interaction between crime and law enforcement. They also emphasize alternative and complementary public policies for controlling crime, i.e., law enforcement and enhanced economic opportunities, and develop (in the expanded model) a description of behavior for communities which can be used to define the demand for law enforcement services. The latter model also considers the elasticity of law enforcement labor supply. While this is unique to the Phillips and Votey model, they find that the estimated elasticity is infinite and, therefore, the wage equation is unnecessary. The model(s), however, does not explicitly recognize the constraint of fiscal capacity, nor does it include interactions among branches of the criminal justice system or levels of government.

The Ehrlich model represents a major theoretical development. With the exception of Sjoquist (and the later model by Phillips and Votey), for the most part, the other models have little theoretical content. The Ehrlich model expands on and refines the work of Becker. As such, it is a contribution. Nevertheless, as an empirical and policy model it is roughly similar to Orsagh. Its policy relevance is limited by the use of observations by states as a data base. Since police activity is primarily a local public sector responsibility, a model focusing on the interactions between crime, crime control, and the local public sector would appear to be more relevant. Such a model should, of course, also recognize impacts of the rest of the criminal justice system, as well as other levels of government.

After Ehrlich's work, there appeared a series of models with a local public sector focus, although not all of them use similar data bases. The Greenwood and Wadycki model emphasizes the interaction between crime rates and public expenditures for police protection. They explicitly consider the local public sector by linking police expenditures to local fiscal capacity. McPheters and Stronge address the same basic problem of adequate description of the simultaneous nature of the interaction between crime rates and expenditures on police protection. Methodologically, however, the McPheters and Stronge paper is superior. One contribution is their use of principal components analysis to construct indices of urban characteristics which have an impact on the amount of criminal activity. Finally, Wilson and Boland take a similar approach, but add the potential impact of police activities, or

patrol strategies, on crime rates. Strategy, they argue, is a political variable as much as, or more so, than an economic one. They also include a police deployment function in their model. Thus Wilson and Boland consider the political realities of law enforcement activity, a dimension missing from the other models reviewed.

While each of these latter models consider the local public sector, they do so incompletely. For one, they ignore the impact of crime on municipal property values and, thereby, on municipal fiscal capacity. The Hellman and Naroff model includes this possibility. Their model focuses on the simultaneous nature of the relationship between crime and property values. This is their contribution. Nevertheless, the Hellman and Naroff model, like the three models listed before it, is an incomplete model of the complex interactions between crime and the local public sector.

C. Model Requirements

Based on our review of previous model building efforts, we have identified a variety of theoretical and empirical developments and have determined the need to incorporate the perspectives of some of the models, as well as to add dimensions which have been largely ignored. Specifically, an adequate policy-relevant model of crime, law enforcement and the public sector requires several elements, some of which are present, in part, in previous models, some of which have not been included:

1. Specification of a simultaneous equation system which can describe the simultaneous nature of the interaction, not only between crime and law enforcement activities, but also among crime, property values, public revenues, and public expenditures, or police budgets.
2. Use of local government as the appropriate focus of the model and, therefore, as the data base for the empirical work.

3. Recognition of the impact of tax base, tax effort, and intergovernmental transfer payments on the revenues available to local government.
4. Recognition of the interactions among various elements of the criminal justice system -- the police, courts and corrections -- and the constraints imposed by one system, or level of government, on the expenditures and outputs of the local government sector, including local police. Such recognition would highlight the role and importance of agency/jurisdictional cooperation within the criminal justice system.
5. Consideration of the impact of other urban characteristics, such as economic well-being and housing quality, on the level of criminal activity in urban areas, and recognition of the potential of these for development of alternative policy for controlling crime. This, in combination with (4), further highlights the role of complementary and cooperative public policy efforts.

In addition to the theoretical structure requirements of the model, there are some methodological requirements:

1. Recognition of the possibility of lagged response of some variables to "causal" factors via introduction of distributed lagged functions.
2. Use of adequate statistical techniques designed for estimation of simultaneous systems of equations. (See Appendix A).
3. Appropriate specification of functions within the system so that each function is properly identified and the impact of each variable within the system can be clearly determined. (See Appendix A).
4. Inclusion in the analvsis of a potentially large number of urban characteristics, which are likely to be highly correlated, by using an appropriate data reduction technique, such as principal components analysis or ridge regression.

With these requirements in mind, we describe a model which meets, or is capable of meeting both the theoretical and methodological requisites outlined. While our focus is on the structure and policy relevance of the model, methodological issues are listed here for the sake of completeness.

D. A General Model

In this section the elements of a model which recognizes the important interactions between the urban public sector and urban crime are defined. The elements include recognition of: 1) the impact of crime on property values and tax base; 2) the impact of tax base, tax effort and intergovernmental transfers on local tax revenues; 3) the impact of both crime and local fiscal constraints on law enforcement expenditures; 4) the impact of criminal justice expenditures on law enforcement productivity; and 5) the impact of law enforcement activity, as well as other variables, on crime. Interactions among components of the criminal justice system, and among levels of government must be accounted for. The model should also include other urban characteristics which affect the level of criminal activity. A model containing these elements is designed to meet the requirements outlined in Section C; it is intended to be useful for urban planning.

A model which incorporates these elements could answer a variety of interesting policy questions, such as:

1. Based on a direct cost/revenue calculation, is it rational for a city to expend more resources on law enforcement?
2. Is it rational given other objectives, e.g., maximization of net benefits rather than net revenues?
3. Do property crimes affect the public budget more so than violent crimes?

4. What "mix" of enforcement appears rational?
5. Is optimum law enforcement from a city perspective consistent with national objectives with respect to crime control?
6. Is it possible to identify points in the urban system where other government jurisdictions impose constraints?
7. Can one hypothesize the impacts of these constraints?
8. Would intergovernmental transfers be appropriate to alter urban law enforcement resource allocation decisions?
9. How does crime interact with other urban problems or urban characteristics, e.g., how does housing quality impact on crime, both directly and indirectly via its impact on property tax revenues?

In the following section the general model outlined briefly here is presented in more specific form for purposes of illustration. The model is defined in terms of market or system interactions, summarized in a set of five simultaneous equations. Each of the equations and markets in the model is discussed in some detail.

SECTION III. A SIMULTANEOUS EQUATION MODEL

The previous review of the literature has revealed several shortcomings in the earlier research and highlighted the path along which model development should proceed in order to provide policy-relevant information. In particular, we have shown the need to identify clearly the relationships between criminal activity and locational preferences, i.e., impacts on property values, and the resulting feedback on revenues, governmental activities and the criminal justice system. In this section, for purposes of illustration we identify the details of a model which might be estimated in order to specify quantitatively these relationships. Included is a discussion of the five subsystems that the model could include and an analysis of the variables that might be included in each (with specific reference to past modelling activities). The purpose is to identify key determinants of behavior within each sub-system and to identify links among them. Econometric and measurement issues which stem from the model development are also discussed.

The model described contains a simultaneous system of equations. While methodologically necessary to ensure consistency and efficiency in estimation, the simultaneous approach has the advantage of stressing the systematic aspects of the interplay of criminal justice agencies in urban settings. Thus, by recognizing both intergovernmental and inter-agency behavioral impacts in a series of interdependent equations, the model highlights the role and importance of agency cooperation within the system. The nature of simultaneous equation models is briefly described in Appendix A. In addition, the appendix describes the methodological requirements for obtaining reliable empirical estimates of simultaneous equation systems.

Two other appendices support the discussion in this section. Appendix B describes how "multipliers" can be derived from the model. The appendix contains an explanation of what the multipliers measure and how they can be used to link the model to various public policy questions or options. This appendix demonstrates the potential value of the model to criminal justice planners and practitioners, as well as to other public sector decision-makers.

Appendix C summarizes the data requirements of the model. While we do not attempt empirical estimation, it is clear that estimation would be required to give measured content to the system described here. Appendix C suggests the possibilities for empirical work by outlining the data requirements.

A. The System Interactions

The model described here is defined in terms of market or system interactions. The system is summarized in five equations, or sub-models: 1) a crime generation or supply of offenses function - a model of criminal activity; 2) a law enforcement production function - a model which describes the output of the criminal justice system; 3) a police services demand function - a model which describes the determinants of police expenditures; 4) a city property value function - an urban property market model; and, 5) a city revenue function - an urban public finance model.

The first three sub-models explain the criminal justice system relationships, while the last two deal with the urban public sector. The criminal justice system equations are themselves related in a simultaneous manner. In this section, the basic relationships among the equations are described. In the following five sections the structure of each individual equation is considered.

The first part of the overall model consists of the criminal justice system equations: the crime generation equation, in which the crime rate is the dependent variable; the law enforcement production function, in which the

conviction rate is used as the measure of output and is, therefore, the dependent variable; and, the police services demand function, in which police expenditures is the dependent variable. The crime rate equation is a model of criminal activity in that it represents a supply function for offenses. As such, the conviction rate and police expenditures are proxies for input prices (potential costs) paid by the criminal who supplies labor to the criminal activity market. The higher the input prices, other things being equal, the less will be supplied.

The crime rate in turn affects both police expenditures and the conviction rate. The conviction rate is a law enforcement production function. The crime rate represents the supply of inputs to the criminal justice system and affects it by partly determining the system workload. The police expenditures function represents the demand for police protection. The crime rate is a shift factor in this function, proxying tastes for protection. Thus: 1) the crime rate enters the conviction rate function as a system input, while the conviction rate represents a cost of producing criminal activity in the crime generation function; and, 2) the level of police expenditures measures a cost of producing criminal activity in the crime generation function, while the crime rate represents a taste for police protection variable in the police expenditures function.

The simultaneity in the three equations is completed by recognition that police expenditures affect the conviction rate. Since the conviction rate (output) is dependent on inputs, and, since the level and distribution of police expenditures help determine the supply of inputs (charged offenders), the police expenditures variable enters the conviction rate function as an indirect input supply variable. As the level of police expenditures increases, other things equal, the supply of inputs, or charged offenders, increases.

The municipal revenue section of the model consists of: a city property value function, in which aggregate property value is the dependent variable;

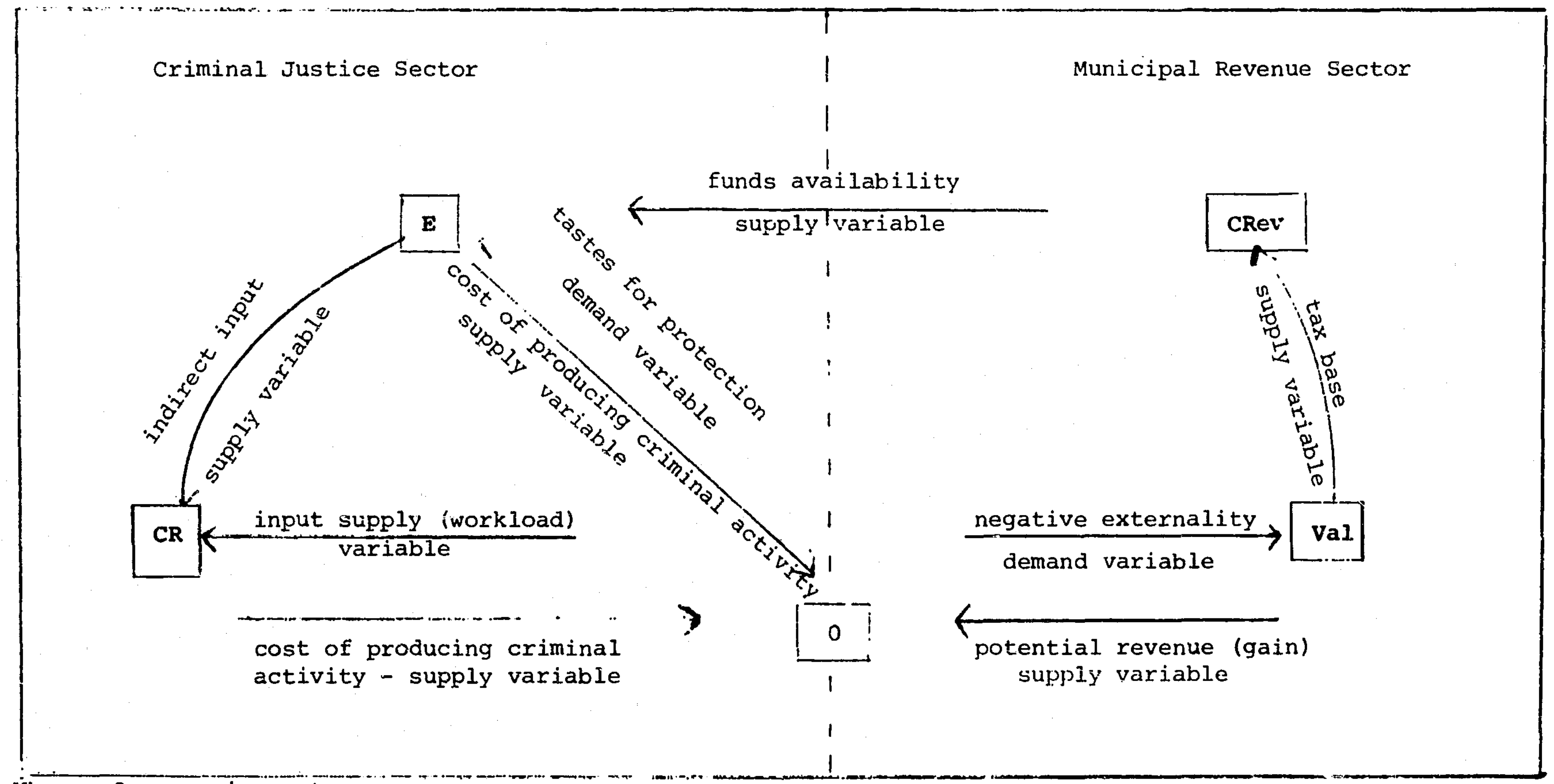
and, a city revenue function, in which city revenue is the dependent variable. The property value equation represents the equilibrium value of property in the urban land market, while the revenue equation is equivalent to a budget constraint for city expenditures. Since the property tax is a major source of revenue for cities, aggregate property values represent a supply of finances, or tax base factor in the city revenue equation. As property values increase, the potential revenue raising capability of the city increases.

The municipal revenue equations are integrated with the criminal justice system equations in two ways. First, the crime rate and property values are related in a simultaneous manner. The crime rate negatively affects the desire of individuals to locate in an area (a negative externality), reducing the demand for property there, and, therefore, reducing property values. Property values, in turn, represent potential gains to labor supplied for criminal activity and so should be positively related to crime rates.

The second way the two sectors are related is through the interaction of the police expenditures and city revenue functions. Police expenditures compete with other needs for a portion of the city budget. As the availability (supply) of funds increases, the possibility that expenditures on all budget line items, including police expenditures, can expand, increases. With the city revenue function affecting the police expenditures function, the dependency between the criminal justice system and the municipal revenue sector is completed. The relationships within and between the criminal justice system sector and the municipal revenue sector of the model are summarized in Figure 3-1. In the following sections we discuss in detail each of the five equations described above.

FIGURE 3-1.

THE CRIMINAL JUSTICE SYSTEM/MUNICIPAL REVENUE RELATIONSHIP



Where: O = crime rate
CR = conviction rate
E = level of police expenditures
Val = value of property
CRev= available municipal revenue

B. The Crime Generation or Supply of Criminal Offenses Function

The first equation(s) we are concerned with is the crime generation or supply of offenses function (O). Since the central hypothesis of the study is that the level of crime affects aggregate property values, the dependent variable in this equation is a crucial variable in the analysis. This variable could take the form of at least three crime measures: (1) a total crime index; (2) a crimes against property index; and, (3) a crimes against persons index. The indices might be in the form of per capita total crimes, means, medians, ratios, or weighted per capita total crimes.

One problem in measuring crime is uncertainty about how people perceive the crime problem, or how perceptions are formed. This is important because the appropriate measure of crime should be included in the model to capture its impact on demand for police services or expenditures, and its impact on location decisions and the value of property. For example, the absolute level of criminal activity in a city, i.e., the number of crimes or the crime rate, may not be as important as the relative position of that city vis-as-vis other cities. A ratio of the per capita city crime rate to the mean or median per capita city crime rate for all cities might therefore be a more logical variable. Secondly, in deriving totals one must ask whether all crimes are equally important to individuals, even crimes within the same crime class, such as crimes against property. For example, do people weigh auto theft in an equivalent manner as burglary? If the response is negative, then a weighted total reflecting relative importance is required. Creation of the crime indices, then, becomes the starting point for any analysis. Unfortunately, the reviewed literature generally considers the supply of offenses (O) to be some simple form of the crime rate.[1]

To understand the level of crime in a city, however measured, it is necessary to look at the socioeconomic structure of the city, the physical structure, e.g., housing, and the operations of the criminal justice system. The first two factors directly or indirectly affect the gains and costs of engaging in criminal activity, while the third is a deterrence factor, representing potential costs to the offender.

The use of socioeconomic variables in the supply of offenses, or crime generation equation, is a common theme throughout the literature. Several variables commonly included in the equation are: median income, percentage nonwhite, unemployment rates, percentage youths, education levels and population density. (See Table 3-1). Since low income or unemployed individuals have low expected punishment costs, other things being equal, they tend to commit more crimes than the general populace. Median income, Y, the unemployment rate, Un, and the percentage of the population below the poverty level, Pov, become three socioeconomic variables which help to explain crime rates. Because the nonwhite population is, on average, poorer and experiences higher unemployment rates than the white population, and because it has been victimized by discrimination, the percentage nonwhite in a city, NW, is also typically included.

Most economic studies have found that these socioeconomic variables, Y, Un, Pov, NW, as well as other variables, are highly correlated. As a consequence, creation of socioeconomic indices, Soc, rather than individual

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1. There has been some discussion in the literature concerning the appropriate crime rate. For example, see Roland J. Chilton and Adele Spielberger, "Increases in Crime: The Utility of Alternative Measures", Journal of Criminal Law, Criminology, and Police Science, Vol. 63, No. 1, March 1972, pp. 68-74; and Itzhak Goldberg, "'True' Crime Rates: The Deterrence Hypothesis Revisited", Hoover Institute, Stanford University, August 1977.

Table 3-1

VARIABLES INCLUDED IN CRIME GENERATION EQUATIONS

Model	Variables Included
Orsagh [18]	Urbanization, economic well being index, change in economic structure, percent of population between 15 and 35, percent black.
Pressman and Carol [23]	Population density, in-migration, income, income distribution, education levels, race, percent in poverty area, climate, number of full-time police.
Allison [1]	Unemployment rate, proportion males, proportion youths, education levels, distance from city.
Sjoquist [29]	Population density, population, percent nonwhite, education levels, probability of punishment, punishment per offense, legal and illegal gains.
Phillips and Votey [20]	Unemployment rates, clearance rate.
Phillips and Votey [21]	Conviction rate, severity of punishment, principal components (factors) - urbanness, poverty,presence of disadvantaged youth, frustrated economic ambition, instability.
Ehrlich [6]	Percent nonwhite, percent young males, unemployment rate, median income, labor force participation rate, probability of punishment, punishment per offense, legal and illegal gains.
Greenwood and Wadycki [8]	Population density, percent nonwhite, percent poverty, value owner-occupied housing, police labor.
McPheters and Stronge [14]	Principal components (factors) - central city decay, central city affluence, education, youth presence, housing quality, police expenditures.
Brantingham and Brantingham [4].	Density.
Wilson and Boland [26]	Population density, percent nonwhite, percent youths, unemployment rate, probability of arrest.
Hellman and Naroff [17]	Density, percent nonwhite, unemployment rate, housing quality, property values.

inclusion of these variables, is necessary methodologically. The indices would be created to measure the characteristics of the (potential) criminal The sign of the relationship between crime and any particular index would depend on the structure of the index itself.

In order to measure the potential income from criminal activity, or victim characteristics, aggregate property values, Val, and median income, Y, should be included in the equation.[2] The problem of distinguishing between the measurement of potential income and potential costs of criminal activity is an issue raised in the literature review section. For example, the variables that Sjoquist considers, percentage of families below the poverty line and unemployment rates, failed to capture this crucial difference. Ehrlich, however, includes legal and illegal gains variables in order to separate the competing effects. In a multi-equation model, property values should unambiguously measure potential income or gains to criminal activity. Since high property values act as a magnet for certain types of crime, such as crimes against property, Val should be positively related to the crime rate. In addition, the higher the income level in a given area, the greater the potential income gains for both crimes against persons and crimes against property. Median income, Y, should exhibit a positive sign when a crime generation function is estimated.

The housing stock, Q, enters into this equation, not simply through aggregate property values and thus potential income gains, but also through an effect on costs of committing crimes. As Brantingham and Brantingham, as well as others, argue, a dense area affords both a measure of anonymity and

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2. See discussion below for full details about the aggregate property value equation.

ease of escape, making densely populated areas a relatively safe place to commit crimes [4].[3] The housing characteristics of an urban area, specifically density, D, should therefore be included. However, since this model considers criminal activity in cities, average density may not be the best density measure. Averaging can distort the true picture of the city. A measure such as the percentage of census tracts in a given city whose density exceeds the average density in the sample, may be superior. With this measure it is possible to determine whether a city with a few tracts with very high density exhibits higher (or lower) crime rates than a city with many tracts of moderate density. In essence this is a procedure which proxies the "lumpiness" of a city's density gradient. Since previous studies have postulated that density should be a significant variable in the crime generation equation but have not uniformly found the variable to be significant in the empirical estimation, it is expected that this alternative approach would better represent the relationship of density to crime rates.

Density, of course, is just one element of the quality of the housing stock that should be considered. In addition, variables such as the percentage of the units which are substandard, percentage of one family houses, percentage of the units having no plumbing, and percentage of the units having more than one person per room could be included when modelling the impact of the housing stock quality on the crime rate.

The crime generation function is completed with the inclusion of the deterrence variables. As Becker and others have argued, the rational criminal considers (or acts as if he/she considers) expected punishment costs of

3. This paper analyzes the relationship between residential burglary and urban form using a mapping technique rather than an econometric model. As a result, it was not critiqued in the literature review section, Section I.

committing a criminal act(s). This depends on the probability of punishment (itself, a joint probability), and the expected punishment, or sentence length. The probability of punishment depends on a series of events: the probability of arrest, the probability of conviction given arrest, and the probability of a given form of punishment, given conviction. To the individual, the fraction of crimes cleared by arrest, AR, the fraction of crimes resulting in conviction, or the conviction rate, CR, average sentence length, f, and the level of the police budget, E, are factors which help determine expected punishment costs, one cost of engaging in criminal activity. The higher the arrest rate, the conviction rate, and the longer the sentence length, the higher the potential costs to the criminal and the fewer the number of criminal attempts, other things being equal.

The level of police expenditures, itself representing the demand for police protection, also affects the crime rate. The higher police expenditures are, or are perceived to be, the higher is the assigned probability of the criminal being placed into the criminal justice system. An increased assigned probability increases the potential criminal's perceived punishment costs and therefore should reduce the level of crime. This deterrent effect is in addition to, and independent of, the impact of police expenditures on the arrest rate.

As noted in the literature review section, a potential problem arises with the interpretation of the sign of the police budget variable in a crime generation function. The criticism of McPheters and Stronge of the Greenwood and Wadycki model focuses this problem as an econometric identification issue. There are several factors to consider. First, the level and make-up of the police inputs will partially affect the arrest rate and the conviction rate, and thus the crime rate. Secondly, the crime rate enters into the decision making process for the police budget in that higher crime rates generally call forth demands for greater expenditure on police services. This implies a two directional relationship between the crime rate and police expenditures. Finally, it must be determined whether police production is being measured in terms of its reporting effort, or its crime prevention effort. These problems can be resolved in a fashion similar to McPheters and Stronge through the inclusion of separate equations for a law enforcement production function and a crime generation function within a simultaneous system. By formulating the model in this manner the sign of the police budget variable should represent the deterrence effect of the police force. The negative sign on the police expenditure variable in the crime generation function of McPheters and Stronge reinforces this expectation.[4]

In summary, crime generation or the supply of criminal offenses, O, measured by one of several possible indices of criminal activity, is hypothesized to be a function of: (1) socioeconomic indices, Soc, which include measures such as median income, Y, percentage of nonwhite, NW, unemployment rates, Un, and percentage poverty, Pov; (2) aggregate property values, Val; (3) median income, Y; (4) housing stock characteristics, Q, including different measures of density, D; (5) the arrest rate, AR; (6) the conviction rate, CR; (7) the average length of sentence, f; and (8) the level of police expenditures, E.

$$O = O\ (Soc,\ Val,\ Y,\ Q,\ D,\ AR,\ CR,\ f,\ E) \qquad (1)$$

In equation (1) the conviction rate enters into the crime generation function as an independent variable. However, from the review of the literature it was shown that this variable (which has been called an enforcement

4. An additional form which the police/deterrent variable could take is a "police strategy" variable, as suggested by Wilson and Boland.

variable) is itself one element of the criminal justice system. As such and as Ehrlich, Wilson and Boland, Orsagh, and Nagin, among others, have argued, this must be considered as a function of the other elements of the criminal justice system. Since we have argued that a full understanding of the criminal/criminal justice system relationship must be explained if we are to model completely the interaction of crime, property values and the public sector, a model of the conviction rate function becomes necessary. This function must adequately incorporate the impact of the various components of the criminal justice system.

C. The Conviction Rate or Law Enforcement Production Function

Although the emphasis in the literature has been on police inputs and activities, the quality, quantity, and structure of police, court, and corrections inputs are the primary determinants of the conviction rate. In addition, various environmental (or service condition) variables have been included in this function (See Table 3-2 for a summary.) Clearly, the level and distribution of court expenditures impact significantly on the conviction rate. The rational criminal is concerned not simply with arrest, but more importantly with the probability of trial and conviction. It is thorugh the trial system that real costs, i.e., time in prison, are imposed on the potential criminal. Total court expenditures per capita, Ct, (a proxy for supply of courtroom services) is a primary input in the production function. The greater the level of expenditures and the larger the number of courts, the higher the probability that an arrest will lead to a court appearance, conviction, and sentencing, other things being equal.

Table 3-2

VARIABLES INCLUDED IN ENFORCEMENT EQUATIONS

Model	Variables
Orsagh [18]	Police labor inputs per capita, crime rate, community size, percent population 15-35, percent black, percent poor.
Ehrlich [6]	Police expenditures, crime rates, population density, percent poverty, percent non-white, education levels, percent youth, North-South dummy.
Phillips and Votey [20]	Law enforcement expenditures, technology, crime rate.
Phillips and Votey [21]	Crime rate, law enforcement personnel.
Wilson and Boland [26]	Patrol strategy, index crimes per number of patrol units, percent nonwhite.
Nagin [16]	See for full review of deterrence effects.

The distribution of court funding, however, may be even more important than the absolute level of court funding. Two factors need to be considered when thinking about the relationship of court funding to crime rates. First, the proportion of funds spent on labor, i.e., justices, (J), versus capital or other expenditures is of prime importance. To the extent that labor is more proportional to output than capital is, as the number of judges increases relative to other inputs, the number of cases heard per unit of time increases.[5]

5. This will be true as long as the change in output from substituting judges for other inputs is positive, that is, there is no excessive courtroom overcrowding.

Second, the distribution between civil and criminal courts, CCV, helps to determine the probability that a given type of criminal offense will reach court action. Other things equal, as proportionately more money is spent on criminal courts, the probability that a criminal case (i.e., for our concerns, crimes against property and persons) will go to trial, rather than be settled by plea bargaining, increases, therefore increasing the potential punishment cost to criminals.[6]

Both of the variables, Ct and J, impact on, and are impacted by the corrections system. First, low levels of court expenditures can lead to crowded court calendars, creating increased pressures on the part of prosecuting attorneys for plea bargaining, as well as administrative processing of criminals, e.g., dropping charges. A second factor, pointed out by Wilson and others, is that crowded prisons may place a constraint on court activity.[7] The average sentence length may be shortened, or charges against individuals committing less serious crimes may be dropped if there is limited correctional space. Consequently, only the more serious criminal charges may be processed. In addition, judges facing the growing "cruel and unusual punishment" doctrine concerning prisons that has recently been applied in many jurisdictions, may be refusing to sentence, or may be reducing sentences, for lesser criminal acts. Inclusion of a variable representing expenditures on corrections, Cor, and one representing the percentage of the available penal institution space

6. For a mathematical model of the choice between trial and pre-trial settlement and identification of factors which favor each possibility, see William M. Landes, "An Economic Analysis of the Courts," The Journal of Law and Economics, Vol. 14, No. 1, April 1975, pp. 61-107.

7. See Stuart Nagel and Marian Neef, "What's New About Policy Analysis Research," Society, September/October, 1979, pp. 24-31; and James Q. Wilson, "Who Is In Prison", Commentary, Vol. 62, No. 5, November, 1976, pp. 55-68, for a discussion of these two points.

which is filled, Cap, is therefore required.[8]

The extent to which the courts may be overloaded is dependent on the activities of the police department in apprehending criminals. The level of police expenditures, E, as well as the proportion spent on direct law enforcement (proxied by the percentage spent on non-administrative activities, NAd), help explain the level of demand for court activity in that they are proxies for the input, accused individuals. As discussed before, the distribution of expenses, in addition to the level of expenses, are potentially significant factors. How the police budget is spent, in terms of the proportion of the budget directed towards direct law enforcement activity, must be accounted for in the model if apprehensions are to be related to conviction rates. As total police expenditures, and as expenditures on non-administrative activities increase, apprehensions should increase, increasing the probability of being caught, tried and convicted.

The final variable to be included in the function is the supply of offenses variable, O. This is a workload proxy. For any given level and distribution of expenditures (or inputs) in the criminal justice system, productivity, as measured by the conviction rate, is likely to be reduced as the supply of offenses increases. This is because to achieve the same rate of conviction (convictions divided by offenses), would require a larger number of arrests and convictions.

The factors discussed, Ct, J, CCV, Cor, Cap, E, NAd, and O, are the major elements, either inputs or constraints, that should be considered in developing

8. What this implies is that the average sentence length is a function of the court variables and the corrections variables and should be included as a separate equation in the system. The conviction rate segment of the model would contain more than one equation.

a conviction rate or production function equation. In addition, there are "environmental" variables that might be considered. For example, several models, such as Orsagh, Ehrlich, and Wilson and Boland, include variables that proxy the issue of access to the criminal justice system. To the extent that the poor and the nonwhite have less access, especially in terms of quality legal representation, as the percentage of poor or nonwhite in an area increases, the tendency is for the conviction rate to increase. Finally, as Ehrlich argues, there may exist a systematic difference in conviction rates, or productivity, across regions that must be accounted for. These two concerns, access to the criminal justice system and regional differences, might be considered in an empirical analysis.[9] Additional environmental variables, as considered by other researchers and summarized in Table 3-2, might also be taken into account.

The conviction rate, or law enforcement production is hypothesized to be a function of: (1) total court expenditures, Ct; (2) percentage spent on labor, J; (3) the distribution of Ct between civil and criminal courts, CCV; (4) total expenditures on correctional facilities, Cor; (5) the percentage of available penal institution space which is filled, Cap; (6) the level of police expenditures, E; (7) the percentage of the police budget which is spent on direct law enforcement, NAd; and (8) the crime rate, O.

$$CR = CR(Ct,\ J,\ CCV,\ Cor,\ Cap,\ E,\ NAd,\ O) \qquad (2)$$

9. These two variables may be included directly into the function if they are considered constraints. If the assumption is that these define different production functions, estimation of different CR functions is required.

The first two equations in the model explain the output, or activities, and the factors determining the activities, of both the criminal justice system and the rational criminal. One is a supply function, O; one is a production function, CR. Society in general is also involved in the criminal/criminal justice system relationship. In particular, society reacts to increasing criminal activity by protecting itself through both the public and private sectors.[10] Privately, their actions are manifested through increased sales in burglar alarms, target hardening devices, private security forces and other related personal actions. Publicly, their concern is frequently manifested through demands placed on the police force, and ultimately through the level of police expenditures. Expenditures on police inputs is one of the most direct ways in which the public reveals its preferences for public protection services. To account for this the third equation in the model is one which specifies a police input/expenditure equation.

D. The Police Expenditure or Demand for Police Services Function

A major public priority is crime deterrence and apprehension. As such, the police input/expenditure function is reactive; the level and distribution of police inputs and expenditures are often a function of the level of criminal activity, O.[11] An increase in crime may induce cities and towns to rearrange the distribution of police inputs in favor of more protective services, and/or to increase the total amount of police expenditures.

10. For a review of private and public deterrence literature, see D. Hellman, J. Naroff, S. Beaton and B. Ianziti, "Incentives and Disincentives to Crime Prevention Behavior," National Institute of Law Enforcement and Criminal Justice, (Washington, D.C., 1978).

11. The police expenditure demand function is derived by maximizing a societal (representative) utility function. Crime is a negative factor in the utility function and as such, an increase in the source of disutility means an increase in police protection in order to maintain a given level of satisfaction.

As a consequence, the police budget should largely be determined by the level of crime. An issue which should be explored is whether total police expenditure is an equivalent function of crimes against persons and crimes against property. Ehrlich, Greenwood and Wadycki, McPheters and Stronge, and Wilson and Boland have all argued, although with slightly different results, that both crimes against persons and crimes against property must be included in the police, or public expenditure equation. (See Table 3-3). The reason for separate inclusion is that there are differential (marginal) impacts on spending of changes in these two crime rates. This hypothesis can be tested by first including the total crime index in the functions and then, in a separate estimation, including the crimes against persons and crimes against property indices described above, and testing for differences through the use of a Chow Test.

An additional question which should be tested is whether the level of police expenditures is determined by the present year's crime rates, or more likely, is a function of previous years' rates. If expenditures are reactive, then a lagged crime rate variable, O_{t-1}, the crime rate in the previous year, or a change in the crime rate, ΔO, should be included in the police expenditure equation. Or, perhaps, as Ehrlich suggests, current year expenditures are a function of the previous year's expenditures, E_{t-1}, since expenditures in any one year are only partially adjusted to desired levels.[12]

12. If the supply of police labor inputs is not perfectly elastic, then as Phillips and Votey [21] argue, a law enforcement personnel subdivision must be considered. There would be two (at least) required, a personnel function and a wage function. See Section I.F above.

Table 3-3

VARIABLES INCLUDED IN EXPENDITURE/INPUTS EQUATIONS

Model	Variables
Orsagh [18]	(Labor inputs): crime rate, gasoline sales, property tax per capita, average income.
Ehrlich [6]	Potential loss from crime, crime rate, expenditures in previous period.
Phillips and Votey [21]	(Wage function): per capita law enforcement personnel, median income, density. (Input function): wages, crime rate, median income, crime mix.
Greenwood and Wadycki [8]	Crimes against both persons and property, average income, per capita property taxes.
McPheters and Stronge [14]	Crime rate, municipal budget constraints, tastes for police protection.
Wilson and Boland [26]	(Labor inputs): crimes against both property and persons, equalized tax base per capita, marginal cost of new officers (starting salary).

The level of the police budget is only one element that public officials consider when the city's total budget is determined. All expenditures are constrained by fiscal capacity or the total level of available, or potential, city revenue, CRev. As revenue increases, all elements of the budget, including expenditures on police and other elements of the criminal justice system, can be increased.[13]

13. All expenditure levels in the budget are not independent, but are to some extent dependent on other levels of expenditures (either as complements or substitutes). Budget expenditures on each of the criminal justice system line items (police, courts, correction facilities) may either be complementary, in that demands for increases in one lead to increases in all, or they may be substitutes in that they compete for scarce criminal justice dollars. What is suggested by this is the interdependence of the criminal justice expenditure variables and the fact that models should account for it, especially since these variables appear in the conviction rate (CR) equation.

When considering available revenue, however, it should be recognized that not all revenue is derived from local or "own" sources, such as local property, income, and/or excise taxes.[14] There are a number of intergovernmental transfers, both state and federal, that must also be considered. In income sharing and transfer formulas, frequently, certain monies are targeted for specific uses. For example, some revenue sharing, Rev, goes specifically to police services. In including a transfer variable, such as revenue sharing, it is possible to determine the partial effect that changes in revenue sharing allotments for police expenditures, or changes in other formulas, have on crime rates. Thus the element of outside control or influence can be recognized here, and measured. Since these external actions reverberate through the model, a better understanding of the impact of state and federal action is made possible. Up to this point, models of crime, law enforcement and the public sector have not considered this source of potential revenues to support police, nor the intergovernmental impacts on local decision-making.

The dependent variable in the police expenditure equation is total expenditures on police services. However, as explained above, total police expenditures, E, may not be the controlling factor in the criminal/criminal justice system interaction. The proportion spent on direct law enforcement (non-administrative) activities should be considered. Adequate analysis should therefore consider these two variables independently; this may require two separate equations. Collapsing them, however, to give a general form of the third equation(s) in the model, police expenditures, E, are hypothesized to be a function of: (1) the crime rate index, or indices, O; (2) the lagged

14. It is suggested by Greenwood and Wadycki that median income, Y, be included in this equation as a "taste for police protection" proxy. Here, Y enters through its impact on available city revenue.

crime rate, O_{t-1}, change in the crime rate, ΔO, or lagged expenditures, E_{t-1}; (3) the level of city revenue, CRev; and (4) targeted intergovernmental transfers, such as revenue sharing, Rev.

$$E = E(O, O_{t-1}, \Delta O \text{ or } E_{t-1}, \text{CRev}, \text{Rev}) \quad (3)$$

The first three equations in the system model the behavior of the criminal and various crime prevention sectors. The last two equations relate these sectors and their activities to the revenues available to the local public sector. Except for the work of Hellman and Naroff, this issue has not been addressed in the literature. The fourth equation in the model is, therefore, a property value function, while the fifth equation is a city revenue function.

E. The Property Value Function - An Equilibrium Land Market Function

In the property value equation, previous models of urban land use and household location choice are extended by considering crime to be a negative externality, or disamenity which enters into the decision to locate, or not locate in a given area. What results is an equilibrium set of land values where the impact of criminal activity is specifically taken into account.

The dependent variable in the equation is aggregate property value within a city. However, there are different categories of property uses. As a result, total property value, aggregate residential property value, and aggregate non-residential, or commercial property value are potential variables which might be used on the left hand side of the equation. By estimating the equation using these different variables, the question of which types of land use and which category of land use is least impacted by crime can be determined. Public policy might then be directed toward controlling

those crimes which reduce property values, and thus potential tax revenues, the most.

The property value equation is probably the most difficult equation to model. The question of how "crime" enters the equation can only be determined through estimation procedures. The problem, again, is the specification of the form that the crime variable should take. Several different forms and possibilities (ratios, totals, indices, etc.) were discussed above, under the crime generation function. The development of a suitable index is crucial to the final policy conclusions that can be drawn from any study.

The crime rate alone, however, cannot effectively explain property values. Estimation of housing functions is one of the best developed areas of urban economics. Typically, both the quality of the housing stock, Q, and the land use mix, LUM, in an urban area affect aggregate property value. Housing stock quality includes various dimensions: mean density, percentage of units that are one family, age of stock, and quality of stock structure (for example, proxied by percentage substandard). The land use mix variable is represented by the relative mix of commercial/industrial use to residential uses, with the possible inclusion of a percentage open space variable. This variable(s) could be used as a policy tool by planners whereby communities can determine the distribution of land across the various potential uses that maximizes their aggregate property value. In addition, with knowledge of the differential impact of different types of crimes on different types of land users, and therefore property values, efforts could be made to distribute crime within an urban area so as to minimize the negative impact of crime on the tax base.

Socioeconomic characteristics of the city, Soc, also determine property values from the demand side. These characteristics may, or may not be the same as those described above in the crime generation equation. However, median income, the unemployment rate, and percentage nonwhite are likely to be factors which in part determine property values. The problem, as mentioned before, is that the socioeconomic and the housing variables are highly correlated. Inclusion of all the variables in the model becomes impossible because of the econometric problem of multicollinearity. To solve this problem indices should be developed, with factor analysis or ridge regression being suggested techniques.

Finally, two other variables are included in the equation. Public services and tax rates both may be capitalized in property values, requiring that their magnitude and/or quality be included in the equation. The available public service package, PS, partially determines the city's desirability as a place of location and, consequently, the demand for property. The "better" the package, the greater the demand for property, and other things being equal, the higher the aggregate property value. One measure typically used to proxy public service quality is per capita educational expenditures. High quality school systems have traditionally been an attracting force in family location decisions. It is assumed that, in general, per capita expenditures proxy the quality of public services. Other measures available are median reading scores for the school system, or median scores on other nation-wide standardized examinations. The determination of the best proxy for the public service package should be part of an empirical study.

The effective tax rate has been shown to be a factor in land prices. There is a large body of literature which argues that property taxes are capitalized in property values in that higher tax rates should mean, ceteris paribus, lower property values. Thus, in order to separate out this effect, the effective property tax rate variable, tx, is included in the property value equation.

Aggregate property value, Val, is hypothesized to be a function of: (1) the crime index, or indices (0); (2) housing stock quality, Q; (3) socioeconomic characteristics of the urban area, Soc; (4) the land use mix, LUM; (5) the public service package, PS; and (6) the effective tax rate, tx.

$$\text{Val} = \text{Val}(0, Q, \text{Soc}, \text{LUM}, \text{PS}, \text{tx}) \qquad (4)$$

F. The City Revenue Function or Budget Constraint

The final equation in the model is the city revenue equation. Since cities are dependent on the property tax as their major source of revenue, available city funds should be primarily a function of aggregate property value, Val. Aggregate property value measures the potential available city revenue, or tax base, and so as it increases revenues can increase. The extent to which the property tax yields future revenue depends not only on property values, but also on the effective property tax rate, tx, and/or a tax effort, TE, variable.

Tax effort is a measure of the extent to which a jurisdiction is taxing its resources. The problem is that cities have varying levels of fiscal capacity, i.e., potential sources and levels of tax revenue. There may even be political or practical upper limits to taxes or tax effort. Tax effort, or relative taxes and tax rates then become important factors in city budget decisions. A typical way to measure tax effort is to take the ratio of the city's tax rate to the national average rate, where the greater the value, the higher the effort, and the less that increases in the tax rate can be used to generate future revenue.

The levels of these tax variables affect both present and future revenue raising possibilities. The relationship may not be a linear one. As the tax rate/effort increases, the possibility, politically, of increasing the rate decreases. At very high levels, it may be almost impossible to increase revenues by raising the rate. In addition, extremely high rates/efforts may act as a disincentive to location in the given jurisdiction, limiting both the demand for property and the economic feasibility of future tax increases. This may lead to lower future income possibilities. If so, these variables enter the city revenue function in a non-linear manner.[15]

Finally, there are other sources of revenue available to the city, such as intergovernmental transfers, IGT. To the extent that some transfer formulas, and therefore value of transfers depend on local tax effort, such as revenue sharing, direct inclusion in the equation may be impossible. Testing for multicollinearity is necessary, and if it exists, must be controlled for. The final component of the model, city revenue, is hypothesized to be a function of: (1) aggregate property value, Val; (2) the effective tax rate, tx; (3) tax effort, TE; and (4) intergovernmental transfers, IGT.

$$CRev = CRev(Val, tx, TE, IGT) \qquad (5)$$

G. The Complete Model

To summarize, the econometric model developed in this section is a five equation system, where several equations, or sub-models, contain possible subdivisions. The interaction of the equations is simultaneous. This allows, with empirical estimation, the testing of the impacts of various policy options and issues. By changing one variable, the impacts on the entire system can be determined. This process is explained in detail in Appendix B.

Combining each of the functions described above, the general form of the

15. In addition, the non-linearity may differ below and above the value "one", where the city rate is equal to the national rate. Dividing the variable into below and above "one" variables is a possibility.

model can be summarized as:

$$O = O(Soc, Val, Y, Q, D, AR, CR, f, E) \qquad (1)$$

$$CR = CR(Ct, J, CCV, Cor, Cap, E, NAd, O) \qquad (2)$$

$$E = E(O, O_{t-1}, \Delta O, \text{ or } E_{t-1}, CRev, Rev) \qquad (3)$$

$$Val = Val(O, Q, Soc, LUM, PS, tx) \qquad (4)$$

$$CRev = CRev(Val, tx, TE, IGT) \qquad (5)$$

where:

AR = The fraction of crimes cleared by arrest

Cap = Percentage of available penal space which is filled

CCV = Distribution of court expenditures between civil and criminal courts

Cor = Per capita expenditures on correctional facilities

CR = Conviction rate

CRev = Level of city revenue

CT = Per capita court expenditures

D = Population density (possibly given by the percentage of city census tracts which exceed the sample average)

E = Police budget (expenditures)

f = Average sentence length

IGT = Intergovernmental transfers

J = Proportion of court funds spent on judges

LUM = Land use mix measure

NAd = Percentage of police budget spent on non-administrative activities

O = Crime rate indices

O_{t-1} = Crime rate in previous year

ΔO = Change in crime rate from previous year

PS = Public service package proxy

Q = Housing characteristics (possibly developed through factor analysis)

Rev = Revenue sharing funds

Soc = Index of socioeconomic characteristics (possibly developed through factor analysis) which includes percentage nonwhite, NW, median income, Y, unemployment rates, Un, and percentage poverty, Pov

TE = Tax effort variable

tx = Property tax rate

Val = Aggregate property value (either the total of all property, residential property, or non-residential property values)

Y = Median income

The model described here incorporates the important interactions among crime in urban areas, the operation of the criminal justice system, and urban public revenues. The crime rate/property value/revenue feedback is central to the model. In addition, interactions among components of the criminal justice system, and among levels of government are recognized. The model also includes other urban characteristics, such as quality of the housing stock and socioeconomic attributes of the population, which may affect the level of urban criminal activity. In this way, the type of model developed here can be used in a variety of ways to facilitate development and evaluation of policies directed toward urban crime control. The model demonstrates how urban crime control is the result of interdependent behavioral decisions made by various public agencies at various levels of government, and how effective crime control requires inter-agency cooperation. One contribution of the model, then, is its emphasis on the complexity of the interactions between the urban public sector and urban criminal activity, and the implications of that complexity for effective policy-making.

SECTION IV. SUMMARY AND CONCLUSIONS

In the previous sections, models of the relationships among crime, law enforcement and the public sector were reviewed and critiqued. Significant developments in the model-building effort were noted, and shortcomings were identified. Review and criticism focused on theoretical foundation, empirical content and methodology, and public policy relevance. Based on this, a set of structural and methodological requirements were outlined for an adequate policy-relevant model of crime, law enforcement and the public sector. With these guidelines in mind, a five equation simultaneous system of urban crime and the public sector was described which meets the requisites. The model includes a supply of offenses, or crime generation function; a law enforcement production function; a police expenditure, or police services demand function; a city revenue function; and, a city property value function.

Thus, this study has accomplished three major things:

1. It provides a summary and critique of a large number of modelling efforts directed at a description of the interaction between crime, law enforcement and the public sector. This summary, arranged in roughly chronological order, permits an historical comparison of model development. The comparison is facilitated by re-casting the various models into common functional forms and variable symbols.
2. The review and critique has focused on the public policy relevance of the various models. This emphasis permits the review to be of value not only to those interested in model-building, but also to those interested in and responsible for interpreting and applying the models within the context of providing improved criminal justice systems in urban areas. The practical

value of the simultaneous system approach, and the parallel between this approach and public agency cooperation, is but one example.

3. A comprehensive model of the interactions between urban crime, the criminal justice system, and urban public revenues is developed and described in detail. This model identifies the elements required for an adequate policy-relevant systematic description. It demonstrates the manner in which urban crime control is the result of interdependent behavioral decisions made by various public agencies at various levels of government.

Information from the model developed in Section III can be used in a variety of ways to facilitate development and evaluation of policies directed toward urban crime control. This potential is outlined in Appendix B, where model multipliers are derived and it is demonstrated how multipliers can be used to link the model to various public policy questions. Policy multipliers can be calculated and used to measure, compare and evaluate the impact of various policy suggestions or options. The multipliers trace the impact of a change in the value of a policy variable through the entire system or set of equations. Therefore, all interactions are taken into account in the policy impact measurements.

In Appendix B, a measure of the impact of a change in the police budget on the crime rate, city property values, and thus city tax revenues is derived. Calculation of this police budget/city revenue multiplier permits a direct cost/revenue analysis of one policy option - increased urban law enforcement via increased police budgets. In a similar way, the impact of other policies, including options beyond those associated with law enforcement, can be assessed. An illustrative table of policy multipliers is included is Appendix B, and policy variables are identified.

In addition to cost/revenue comparisons of policy impacts, estimated parameters of the model can be used in other ways. Depending on the objective function of the urban decision-maker, optimum law enforcement can be defined and implications identified. The objective function can be varied consistent with different levels of sophistication on the part of decision-makers, e.g., maximization of net revenues to the city, maximization of net benefits to the city, maximization of net social benefits, etc.

Finally, the interjurisdictional and inter-agency impacts of the law enforcement decision can be examined, including federal and state impacts on local law enforcement. The impacts of the constraints can be hypothesized, and the need or role of intergovernmental transfers in the urban law enforcement resource allocation decision-making process can be assessed.

The consistency of municipal and national objectives or priorities with respect to crime control can be evaluated and, based on this, the implications or requirements for alignment of objectives and priorities can be defined. The need for and effectiveness of intergovernmental transfers as incentives to crime prevention behavior by municipalities can be examined using the empirical estimates.

Thus the model developed here is rich enough so that parameter estimates would permit analysis of a variety of interesting policy questions. In this way the model represents a contribution to the existing body of knowledge. Previous modelling efforts have suffered from lack of appropriate empirical content, use of inappropriate methodologies, or incomplete and inadequate specification of the relationships among crime, law enforcement and public budgets. With the essential links among these processes and components identified and measured, including inter-agency and inter-jurisdictional links, more practical policy prescriptions will follow and the stage can be set for complementary and cooperative efforts at urban crime control.

The model developed here is a first step. Collection of a data base consistent with the model requirements (outlined in Appendix C) and estimation of the parameters so that the policy multipliers identified can be given measurable content are areas in which future research work might fruitfully be directed.

APPENDIX A. SIMULTANEOUS EQUATION MODELS

The model presented in the text is a simultaneous system of equations. The use of a simultaneous equation model is necessary because of the many interdependencies described. Criminal activity is not simply a variable that is to be explained, but it is also an element in the police expenditures, law enforcement production and urban property value equations. The police expenditure variable is both a dependent variable, and an independent variable in both the supply of crime and law enforcement production (conviction rate) equations. Property values enter the city revenue equation, while city revenue enters the police expenditures equation. Thus, there is total interaction among the variables. In a real sense, of course, the interaction among variables and equations translates into agency and sector interactions within both the criminal justice system and the entire urban socio-economic system of which it is a part.

If a model is developed which does not properly account for these interrelationships the results can be misinterpreted, or may even be meaningless. An example of this is the literature on the deterrence value of police. Early single-equation models, such as Pressman and Carol [23], and Allision [1], find that police activity is not a significant determinant (i.e., deterrent) of criminal activity. Greenwood and Wadycki's simultaneous model indicates that the sign of the coefficient of police labor in the crime generation equation is positive [8]. That is, either more police mean more crime, or, as they argue, more police mean that more crimes are reported.

However, McPheters and Stronge argue that these models simply misspecify the crime generation equation in that there is no recognition of the simultaneous relationship between crime rates and police inputs or expenditures [14]. Only when this simultaneity is accounted for can the real question of whether the police act as deterrents to crime be tested. Thus a simultaneous system approach is necessary. While Greenwood and Wadycki do use a simultaneous equation approach which permits some system interactions, the structure of their model does not recognize the simultaneous interaction of police inputs/expenditures and criminal activity. Thus a simultaneous equation model alone is not enough. It must be properly specified.

In the model presented in the text, a multi-equation, simultaneous system of the interactions among criminal activity, the criminal justice system, urban property values, and city revenues is described. Such a specification is methodolocally appropriate; it permits "true" relationships within the system to be determined.

In econometric modelling, there is a basic assumption that there exist separate dependent and independent variables. The implication is that there is a given, one-way direction of causality; the independent variables determine, or "explain", the dependent variable(s). However, there often exist interrelationships among the independent and dependent variables such that the one-way relationship no longer can be considered valid. When this situation holds, the problem of simultaneity exists.

If simultaneity exists, as it does in the situation described here, the model cannot be estimated in a single equation form, but a series of equations must be specified. The simultaneous model will consists of "n" equations, where n is equal to the number of variables which are to be "explained by," or determined within the system of equations. These endogenous, or dependent variables are then determined by a set of exogenous or pre-determined

variables. The exogenous variables are those who values are determined or "explained" outside of the system described. Pre-determined variables include exogenous variables and endogenous variables which enter the model in lagged form, i.e.,their prior period values. In that sense their values are pre-determined.

If the model is empirically estimated, two basic problems are encountered: (1) the error term is no longer independent of the explanatory variables,or regressors; and (2) identification of structural parameters is not always possible. The implication of problem (1), the correlation of the error term with the regressors, is that ordinary least squares estimation cannot be employed because the estimated coefficients will be biased and inconsistent. A different form of estimation procedure must therefore be used. Three stage least squares, or another simultaneous system estimation procedure can provide consistent estimates.

The second problem, identification, must be overcome before estimation can take place. The identification problem arises when "the same two variables appear in at least two different stochastic equations in a simultaneous model."[1] When this occurs, other information is necessary in order that the true impact of each variable in each equation can be determined. This additional information is obtained from the exogenous variables included in the model.

The general identification rule that must hold in order for a system of equations to be solved explicitly for the impact of each separate endogenous variable is: the number of exogenous variables excluded from each equation must be at least equal to the number of endogenous variables included in the right hand side of the equation. This rule allows for solution of the

1. James L. Murphy, Econometrics, Irwin Press, 1973, p. 406.

"reduced form" of the model, where the equations are re-written in a mathematically equivalent form with the endogenous variables expressed as a function of only the exogenous or pre-determined variables. The rule, then, is the same as stating that in order to solve a set of equations with "n" unknown variables, there must be at least "n" independent equations. The model described in the text is properly identified; the individual impact of each variable can therefore be determined.

APPENDIX B. MULTIPLIERS: A GUIDE TO MODEL OUTPUT

The model described in the text is a simultaneous equation system containing five equations with five endogenous variables (O, CR, E, Val and CRev) and 20 exogenous or pre-determined variables. The model described in Section III (with symbols in slightly different order) is:

$$O = O(CR, E, Val, Soc(Un, NW, Y, Pov), Q, f, Y, D, AR) \quad (1)$$

$$CR = CR(E, NAd, Ct, CCV, Cor, Cap, J, O) \quad (2)$$

$$E = E(O, CRev, Rev, O_{t-1}, \Delta O, \text{ or } E_{t-1}) \quad (3)$$

$$Val = Val(O, PS, tx, LUM, Soc, Q) \quad (4)$$

$$CRev = CRev(Val, tx, TE, IGT). \quad (5)$$

The coefficients of the variables in each equation (not specified or estimated here) measure the partial change in the dependent variable given a change in the independent variable. However, with a simultaneous system, a change in one independent variable may change not only the dependent variable of the equation, but also other variables which interact with that dependent variable. Therefore, it is not possible to look simply at the coefficient of a variable in any one equation to get a measure of that variable's full impact on the system; rather, it is necessary to solve for the system "multiplier." This multiplier accounts for the full interdependencies among variables in the model.

Solving for the system multipliers makes it possible to determine answers to a variety of policy questions. In this section several of the multipliers are derived in a general form. The solution is described as an iterative process. A change in a variable causes an initial variation in the dependent variable in the equation(s) in which it appears. This change in the dependent variable will then affect the values of all other dependent variables in equations in which the first dependent variable appears on the right hand side. This initial impact is called a first-round effect. These effects will then reverberate through the system triggering additional changes in the dependent variables. When the reverberations are complete, the final magnitude of the disturbance, the sum of the first through *n*th-round effects, is determined.[1]

For policy purposes, the first-round and full-round multipliers may be considered to be measures of short and long-term impacts, respectively. The difference between the short and long-term magnitudes may be small. However, only through observing the effects through the *n*th round is it possible to appreciate fully the impact of any given policy on the entire system. In this section we demonstrate how the first-round multipliers are determined, and answer an illustrative policy question. The system solution which generates full-round multipliers is presented in general matrix notation in the final section.

A. Multiplier Derivation

In order to understand how multipliers can be derived from the model, consider the general form of an estimated model. Subscripted letters are used to represent variable coefficients, and the symbol '^' is used to indicate that the coefficients are estimated by a statistical procedure, rather than known with certainty:[2]

1. Technically, the full-round multipliers need not be computed interatively. Each full-round multiplier can be obtained by calculating its total derivative. The solution to the system of equations, from which total derivatives are desired, is contained in the final section of the appendix.

2. For this discussion assume all equations are in log-linear form. This is to facilitate the discussion. The reason is that in this form the coefficients represent elasticities. The elasticities directly relate a percentage change in the right-hand-side variable to a percentage change in the left-hand-side variable. Thus, in the examples presented, a direct comparison of percentage changes can be made.

$$0 = \hat{a}_1 + \hat{a}_2 CR + \hat{a}_3 E + \hat{a}_4 Val + \hat{a}_5 Soc + \hat{a}_6 Un + \hat{a}_7 Q + \hat{a}_8 f + \hat{a}_9 Y + \hat{a}_{10} D + \hat{a}_{11} AR \quad (6)$$

$$CR = \hat{b}_1 + \hat{b}_2 E + \hat{b}_3 NAd + \hat{b}_4 Ct + \hat{b}_5 CCV + \hat{b}_6 Cor + \hat{b}_7 Cap + \hat{h}_8 J + \hat{b}_9 0 \quad (7)$$

$$E = \hat{c}_1 + \hat{c}_2 0 + \hat{c}_3 CRev + \hat{c}_4 Rev + \hat{c}_5 0_{t-1} \quad (8)$$

$$Val = \hat{d}_1 + \hat{d}_2 0 + \hat{d}_3 PS + \hat{d}_4 tx + \hat{d}_5 LUM + \hat{d}_6 SOC + \hat{d}_7 Q \quad (9)$$

$$CRev = \hat{e}_1 + \hat{e}_2 Val + \hat{e}_3 tx + \hat{e}_4 TE + \hat{e}_5 IGT \quad (10)$$

From this description one can see that a change in either the endogenous or exogenous variables will create a reverberation through the entire system of equations. For example, assume that a city decides to increase its expenditures on police activities. This will cause the variable, E, to increase. To determine the full effect of this change it is necessary to trace the impact through the system.

An increase in E has its initial impact on equations (6) and (7), the crime generation equation and the conviction rate equation. The extent of the impact in these equations is determined by the estimated coefficients, $\hat{a}_3$ and $\hat{b}_2$, multiplied by the percentage change in E, i.e.:

$$\Delta 0 = \hat{a}_3 \Delta E \quad (11)$$

and

$$\Delta CR = \hat{b}_2 \Delta E. \quad (12)$$

This is the start of a complex chain of events, since changes in 0 will cause changes in E via equation (8), in Val via equation (9), and in CR via equation (7), while the changes in CR cause 0 to change further, i.e.:

$$\Delta E = \hat{c}_2 \Delta 0 = \hat{c}_2 \hat{a}_3 \Delta E \quad (13)$$

$$\Delta Val = \hat{d}_2 \Delta 0 = \hat{d}_2 \hat{a}_3 \Delta E \quad (14)$$

$$\Delta CR = \hat{b}_9 \Delta 0 = \hat{b}_9 \hat{a}_3 \Delta E \quad (15)$$

$$\Delta 0 = \hat{a}_2 \Delta CR = \hat{a}_2 (\hat{b}_2 \Delta E + \hat{b}_9 \hat{a}_3 \Delta E) = (\hat{a}_2 \hat{b}_2 + \hat{a}_2 \hat{b}_9 \hat{a}_3) \Delta E \quad (16)$$

where equation (11) is substituted for ΔO and equations (12) and (15) are substituted for ΔCR.

Additional effects then occur, since changes in E, Val and O enter into all of the equations. This may seem to be an endless process, but the reverberations may settle down very quickly. The magnitudes of the effects fall rapidly on the second and third rounds if initial percentage changes become smaller second round percentage changes, and so on, through the system and through successive rounds.[3]

B. Policy Multipliers

Once the full-round multipliers are determined, the effect of increasing the police budget on all the dependent variables in the model can be calculated. In this discussion first-round multipliers are calculated, providing short-term answers to policy questions. This is accomplished by solving for each of the five equations in a manner that exhibits the change in each endogenous, or dependent variable, given a change in another endogenous and/or exogenous variable.

For example, a potential policy question is: based on a direct cost/revenue calculation is it rational for a city to expend more resources on law enforcement? To answer this, it is necessary to solve for $\Delta CRev$ as a function of ΔE. To do so, rewrite equations (6)-(10) as difference equations in terms of the endogenous variables:

$$\Delta O = \hat{a}_2 \Delta CR + \hat{a}_3 \Delta E + \hat{a}_4 \Delta Val \qquad (17)$$

$$\Delta CR = \hat{b}_2 \Delta E + \hat{b}_9 \Delta O \qquad (18)$$

$$\Delta E = \hat{c}_2 \Delta O + \hat{c}_3 \Delta CRev \qquad (19)$$

$$\Delta Val = \hat{d}_2 \Delta O \qquad (20)$$

3. Clearly, how quickly the reverberations settle and the stability of the model depend on the magnitudes of the coefficients and characteristics of the system solution. Empirical estimation is required for a conclusion.

$$CRev = \hat{e}_2 \Delta Val. \qquad (21)$$

Equation (21) indicates that the change in city revenue is equal to $\hat{e}_2$ multiplied by the change in aggregate property values. Substituting equation (20), the change in property value equation, into equation (21) yields:

$$CRev = \hat{e}_2 \, \hat{d}_2 \Delta O. \qquad (22)$$

Equation (22) expresses the change in city revenue, given a change in the crime rate. To complete the policy analysis it is necessary to express the change in the crime rate as a function of changes in police expenditures, i.e., to solve for ΔO as a function of ΔE. Substituting equation (18) into (17) yields:

$$O = \hat{a}_2 \hat{b}_2 \Delta E + \hat{a}_3 \Delta E + \hat{a}_2 \hat{b}_9 \Delta O = \frac{(\hat{a}_2 \hat{b}_2 + \hat{a}_3)}{(1-\hat{a}_2 \hat{b}_9)} \Delta E \qquad (23)$$

since on the first round, $\Delta Val = 0$. A second round solution would incorporate equation (20) where changes in the crime rate change property values. This round is not calculated here for mathematical simplicity.

Finally, substituting equation (23) into equation (22) gives:

$$\Delta CRev = \frac{\hat{e}_2 \hat{d}_2 (\hat{a}_2 \hat{b}_2 + \hat{a}_3)}{(1-\hat{a}_2 \hat{b}_9)} \Delta E \qquad (24)$$

Thus, the first round impact of a change in police expenditures on city revenue is given by equation (24). Since $\hat{e}_2$, $\hat{d}_2$, $\hat{a}_2$, $\hat{b}_2$, $\hat{a}_3$ and $\hat{b}_9$ would be known if the model were estimated, a benefit/cost ratio can be calculated. For example, assume a ten percent change in the police budget, i.e., $\Delta E = .10$. This is multiplied by $\left[\hat{e}_2 \; \hat{d}_2 \; (\hat{a}_2 \hat{b}_2 + \hat{a}_3)\right] / (1-\hat{a}_2 \hat{b}_9)$, the police expenditure-city revenue multiplier to give the percentage change in city revenues. Since present levels of city revenue and police expenditures are known for cities, the dollar values of ΔE and $\Delta CRev$, given the percentage change in E and CRev, can be directly compared.

This, of course, is simply an illustration and does not include second and later round effects. For example, equation (20) indicates that a change in the crime rate will change property values. This directly changes city revenue, described in equation (21), and also changes the level of crime generation, as described in equation (17). From equation (18) it is seen that a change in the crime rate changes the conviction rate, which in turn also changes the level of crime generation. Changes in crime will also change policy expenditures, via equation (19), and the change in city revenue will occasion additional changes in police expenditures via the same equation. A new round is thus set off. The first round, therefore, underestimates the total effect.

TABLE B-1

SHORT-TERM
POLICY MULTIPLIERS

Policy Variables:	Endogenous Variables				
	$\Delta CRev$	ΔO	ΔCR	ΔVal	ΔE
ΔE	$\frac{\hat{e}_2\hat{d}_2(\hat{a}_2\hat{b}_2+\hat{a}_3)}{(1-\hat{a}_2\hat{b}_9)}$	$\frac{\hat{a}_2\hat{b}_2+\hat{a}_3}{(1-\hat{a}_2\hat{b}_9)}$	$\frac{\hat{b}_2+\hat{b}_9\hat{a}_3}{(1-\hat{a}_2\hat{b}_9)}$	$\frac{\hat{d}_2(\hat{a}_2\hat{b}_2+\hat{a}_3)}{(1-\hat{a}_4\hat{d}_2)}$	
ΔUn	$\hat{e}_2\hat{d}_2\hat{a}_6$	$\hat{a}_6$	$\hat{b}_2\hat{c}_2\hat{a}_6+\hat{d}_2\hat{a}_6+\hat{b}_9\hat{a}_6$	$\hat{d}_2\hat{a}_6$	$\hat{a}_6(\hat{c}_2+\hat{c}_3\hat{e}_2\hat{d}_2)$
Δf	$\hat{e}_2\hat{d}_2\hat{a}_6$	$\hat{a}_8$	$\hat{b}_2\hat{c}_2\hat{a}_8+\hat{b}_9\hat{a}_8$	$\hat{d}_2\hat{a}_8$	$\hat{c}_2\hat{a}_8+\hat{c}_3\hat{e}_2\hat{d}_2\hat{a}_8$
ΔCCV	$\hat{e}_2\hat{d}_2\hat{a}_2\hat{b}_5$	$\hat{a}_2\hat{b}_5$	$\hat{b}_5$	$\hat{d}_2\hat{a}_2\hat{b}_5$	$\hat{c}_2\hat{a}_2\hat{b}_5$
Δtx	$\hat{e}_3$	$\hat{d}_4+\hat{a}_3\hat{c}_3\hat{e}_3$	$\hat{b}_2\hat{c}_3\hat{e}_3+\hat{b}_9\hat{d}_4+\hat{b}_9\hat{a}_3\hat{c}_3\hat{e}_3$	$\hat{d}_4$	$\hat{c}_3\hat{e}_3$

Sample short-term policy multipliers are contained in Table B-1. The table indicates the impact of various selected policy variables on the five endogenous variables in the model. The change in an endogenous variable is measured by the product of the indicated multiplier and the change in the policy variable, i.e.:

$$\Delta \text{ Endogenous Variable} = (\text{Multiplier})\ (\Delta \text{ Policy Variable}). \quad (25)$$

The general multipliers can be replaced, of course, by computed numerical values. In addition, multipliers for other policy variables can be calculated. Table B-2 lists and defines the policy variables included in the model. Each of the policy variables has a potential impact on city crime rates, property values, revenues, and police expenditures. Yet the decision-makers responsible for the policy choices indicated in Table B-2 include local, state and federal public officials in a variety of program areas, both within and outside of criminal justice. Thus the inter-agency and intergovernmental behavioral impacts of the policy decisions modelled in the system are highlighted.

The policy variables listed include exogenous variables and three endogenous variables, police expenditures, the conviction rate, and city revenues. While police expenditures, E, are endogenous and therefore determined by values of the other variables in the system, they can be increased or decreased independently if "tastes" for police expenditures change. This would be reflected in a shift in the police expenditures function, i.e., a change in the value of the intercept, c_1. Similar arguments can be made for including the endogenous variables CR, the conviction rate, and CRev, city revenues. For example, a relaxation of constraints on the criminal justice system may be reflected in a shift in the conviction rate function, and introduction of new sources of local revenue would shift the city revenue function. Both of these examples are policy options, although perhaps less obvious than some of the others listed. Finally, among the exogenous variables, the feasibility or immediacy of policy impacts also varies. The tax rate, for example, is subject to a more direct and predictable impact as the result of a policy decision than is the land use mix or median income. Nevertheless, all variables with the potential for change through policy design have been included.

Multipliers are not required to answer all policy questions. For example, the direct impact of a change in intergovernmental transfer payments on city revenues is measured by the coefficient, $\hat{e}_5$; the direct effect of prison capacity on the conviction rate is captured in the coefficient, $\hat{b}_7$. There are many other examples. These measures, however, capture only the immediate direct impact on the dependent variable in the equation. Multipliers account for the reverberations which initial changes trigger throughout the system of interdependent equations.

TABLE B-2

POLICY VARIABLES

Exogenous Variables	Description
AR	Arrest Rate
Cap	Percentage of Available Penal Institution Space Filled
CCV	Distribution of Funds Between Civil and Criminal Courts
Cor	Total Expenditure on Correction Facilities
Ct	Total Court Expenditures
f	Average Sentence Length

Exogenous Variables	Description
IGT	Intergovernmental Transfers
J	Funds Spent on Labor (Justices)
LUM	Land Use Mix
NAd	Proportion of E spent on Law Enforcement
PS	Public Service Package Per Capita (Educational Expenditures)
Q	Housing Characteristics Age Quality Percentage One Family Units Density
Rev	Targeted Intergovernmental Transfers
Soc	Socio-economic Characteristics Median Income Unemployment Rate Percentage Poverty
TE	Tax Effort (City Rate/National Average Rate)
tx	Effective Tax Rate
Endogenous Variables	**Description**
CR	Conviction Rate
CRev	Level of City Revenue
E	Police Budget Expenditures

C. Long-term Multipliers

Table 1 contains sample short-term multipliers. The values which the coefficient symbols represent would not measure the full and complete impact of a change in a policy variable. The full measure is derived from the solution of the reduced form of the model. In its reduced form, the endogenous variables are expressed as functions of only exogenous or pre-determined (exogenous plus lagged endogenous) variables. This is best illustrated by expressing the system in matrix form:

$$\mathbf{A}\mathbf{Y}_t = \mathbf{B}\mathbf{Y}_{t-1} + \mathbf{C}\mathbf{X} \qquad (26)$$

where $\mathbf{Y}_t$ is a five by one vector containing the five endogenous variables; $\mathbf{Y}_{t-1}$ is a five by one vector containing the lagged endogenous variables; and $\mathbf{X}_t$ is a twenty-four by one vector of the five constant terms and the nineteen exogenous variables, i.e.:

$$\mathbf{Y}_t = \begin{bmatrix} O \\ CR \\ E \\ Val \\ CRev \end{bmatrix} \qquad \mathbf{Y}_{t-1} = \begin{bmatrix} O_{t-1} \\ CR_{t-1} \\ E_{t-1} \\ Val_{t-1} \\ CRev_{t-1} \end{bmatrix} \qquad \mathbf{X}_t = \begin{bmatrix} a_1 \\ b_1 \\ c_1 \\ d_1 \\ e_1 \\ \hdashline Soc \\ Un \\ Q \\ f \\ Y \\ D \\ AR \\ NAd \\ Ct \\ CCV \\ Cor \\ Cap \\ J \\ Rev \\ PS \\ tx \\ LUM \\ TE \\ IGT \end{bmatrix}$$

A is a five by five matrix of coefficients of the five endogenous variables in each of the five equations; **B** is a five by five matrix of the coefficients of the lagged endogenous variables in each equation; and C is a five by twenty-four matrix of coefficients of the twenty-four constant terms and exogenous variables in each of the five equations, i.e.:

$$\mathbf{A} = \begin{bmatrix} 1 & -a_2 & -a_3 & -a_4 & 0 \\ -b_9 & 1 & -b_2 & 0 & 0 \\ -c_2 & 0 & 1 & 0 & -c_3 \\ -d_2 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -e_2 & 1 \end{bmatrix} \qquad \mathbf{B} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ c_5 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

and

$$\mathbf{C} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & a_5 & a_6 & a_7 & a_8 & a_9 & a_{10} & a_{11} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & b_3 & b_4 & b_5 & b_6 & b_7 & b_8 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & c_4 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & d_6 & 0 & d_7 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & d_3 & d_4 & d_5 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & e_3 & 0 & e_4 & e_5 \end{bmatrix}$$

Solution for the reduced form yields:

$$\mathbf{Y}_t = \mathbf{A}^{-1}\mathbf{B}\mathbf{Y}_{t-1} + \mathbf{A}^{-1}\mathbf{C}\mathbf{X}_t \qquad (27)$$

The current values of the endogenous variables are expressed as a function of the lagged endogenous variables and the exogenous variables.

The complete solution of the system accounts for the sequential impact of the lagged endogenous variables on future values of the endogenous variables:

$$\mathbf{Y} = (\mathbf{I} - \mathbf{A}^{-1}\mathbf{B})^{-1}\mathbf{A}^{-1}\mathbf{C}\mathbf{X} \qquad (28)$$

The solution described in equation (28) indicates matrix operations on values of the coefficients which would fill the cells of **A, B, C** and part of **X**. Full-round multipliers are represented by the solution matrix elements. Each element measures the full change in an endogenous variable caused by a change in an exogenous variable, or by an initial change in an endogenous variable caused by a shift in its functional intercept. Thus full-round multipliers can be obtained from the system of empirically estimated coefficients.

APPENDIX C. MODEL DATA REQUIREMENTS

Table C-1 summarizes the data requirements of the model described in the text by listing and defining each of the variables mentioned in Section III. In addition, each variable is roughly linked to available sources of information. Table C-2 describes the major data sources and contains a brief discussion of the kinds of data contained in each.

TABLE C-1

VARIABLES AND DATA SOURCES

Variable	Description	Source (from Table C-2)
AR	Arrest Rate	12, 18
Cap	Percentage of Available Penal Institution Space Filled	20
CCV	Distribution of Funds Between Civil and Criminal Courts	24
Cor	Total Expenditure on Correction Facilities	13, 15
CR	Conviction Rate	12, 16, 19, 21
CRev	Level of City Revenue	5, 11
Ct	Total Court Expenditures	12, 15, 17
E	Police Budget Expenditures	11, 15, 24
f	Average Sentence Length	20
IGT	Intergovernmental Transfers	5, 7, 11, 26
J	Funds Spent on Labor (Justices)	12, 15, 17
LUM	Land Use Mix: Commercial, Industrial, Residential, Exempt	City Government Offices of Real Property and Taxation
NAd	Proportion of E Spent on Law Enforcement	24, 27
O	Crime Rate Index	11, 12, 16, 19 and derived

Variable	Description	Source (from Table C-2)
O_{t-1}	Lagged Crime Rate Index, Indices	11, 12, 16, 19 and derived
ΔO	Change in Crime Rate Index	Derived
PS	Public Service Package Per Capita (Educational Expenditures)	6, 11
Q	Housing Characteristics	
	Age	8
	Quality	8, 9
	Percentage One Family Units	8, 9
	Density	8, 11
Rev	Targeted Intergovernmental Transfers	5, 7, 11, 26
Soc	Socio-economic Characteristics	
	Median Income	11
	Unemployment Rate	22
	Percentage Nonwhite	8, 22
	Percentage Poverty	11
TE	Tax Effort	
	City Rate/National Average Rate	23, 26
tx	Effective Tax Rate	23
Val	Aggregate Property Values	
	Assessed Valuation	1
	Full Value	21

TABLE C-2

DATA SOURCES GUIDE

I. Department of Commerce, Bureau of the Census

1. Census of Governments, Vol. 2, Taxable Property Values and Assessment/Sales Price Ratios

   Data on assessed values of real property for SMSA counties, selected major cities; assessments and sales for selected cities and selected tax and assessment ratios for most cities (population over 50,000). Five year intervals.

2. Government Employment, City Employment

   Employment and payroll data by function in summary form and for individual cities. Published annually.

3. Government Employment, Public Employment

   Published annually.

4. Government Employment and Local Government

   Employment in selected metropolitan areas and large counties. Published annually, except 1977.

5. Government Finance, City Government Finances

   Data on city finances including general and intergovernmental revenue and general expenditures for cities, with greater detail for large cities. Published annually.

6. Government Finance, Finances of School Districts

   Revenue, expenditure and enrollment data for school districts over 5,000. Published annually.

7. Government Finance, Taxes and Intergovernmental Revenues of Counties, Municipalities and Townships

   Summary data for revenue sources to local government. Published annually.

8. Annual Housing Survey, General Housing Characteristics

   Data on age, number of units in structure, measures of quality for housing stock, given by SMSA and central city. Published annually.

9. Annual Housing Survey, Indicators of Housing and Neighborhood Quality

Special data section for Annual Housing Survey, (8). Published annually.

10. Annual Housing Survey, Financial Characteristics of the Housing Inventory

Special data section for Annual Housing Survey, (8). Published annually.

11. County and City Data Book

Major data source for population, per capita income, revenues from taxes and intergovernmental sources, expenditures for education and police and fire protection, municipal employment levels including police, various crime indices. Published every five years.

II. Department of Justice, Law Enforcement Assistance Administration

12. Sourcebook of Criminal Justice Statistics

Major data source for statistics on the criminal justice system including expenditure and employment levels for police and judicial, victimizations, arrests, prison populations, by state, by level of government and by function. With an annotated list of sources and references. Published annually.

13. Census of State Correctional Facilities

Data on size, function, personnel and finances for state facilities. Published annually.

14. Characteristics of the Criminal Justice System

Summary data on criminal justice agencies, police, courts and corrections. Published annually.

15. Expenditure and Employment Data for the Criminal Justice System

Data on expenditures and employment levels at the Federal, State and local levels for the criminal justice system by function and by state and for selected cities. Published annually.

16. National Crime Survey, Criminal Victimization Surveys, City Reports Series

Data on number and type of victimization, characteristics of victims and events. For selected major cities, beginning in 1972. Published periodically.

17. National Survey of Court Organization, with Supplements

Summary data for states on courts, jurisdictions, judicial and support personnel. Published annually.

18. State Court Caseload Statistics: Annual Reports

Yearly data reflecting judicial caseload activity in each state court, general and appellate jurisdiction.

III. Department of Justice, Federal Bureau of Investigation

19. Uniform Crime Reports, Crime in the United States

Data on crime, arrests, law enforcement employment. Published annually.

IV. Department of Justice, Bureau of Prisons

20. Bureau of Prisons Reports

Data compares current population to planned capacity for 57 federal correctional institutions. Monthly series.

21. Federal Prison System Statistical Reports

Data on prison population characteristics and movements. Published annually.

V. Other

22. National Commission on Employment and Unemployment Statistics

Contains basic employment data breakdown. Various reports commissioned. Summary final report published September, 1979.

23. State Departments of Taxation

Full value tax rates and equalization ratios. Annual reports by each state.

24. Municipal Budgets

Annual budgets of each city.

25. Administrative Office of the U.S. Courts, Annual Report of the Director

Data on personnel in the federal judiciary, expenditures, workload, civil and criminal cases.

26. Initial State and Local Data Elements, Department of Treasury, Office of Revenue Sharing

Elements that enter into the revenue sharing allotments, by local jurisdiction, by allotment period.

27. The Police Employment Guide

Published by the National Employment Listing Service for the Criminal Justice System. Information about employment in police departments, department size and organization, entrance requirements and starting salaries. For 250 cities with over 50,000 population. 1978.

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