Non-Monotonic Supply of Crime Functions: 
A Replicatory Study

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I. Replication

Economists have begun to pay more attention to replication in recent years. Without replicatory studies econometric work lacks the direction expected of scientific work and becomes mere empiricism: a pointless piling up of non-comparable results. Four types of replication have been distinguished [MITTELSTAEDT & ZORN (1984) p. 10]. The present study is a Type II replication as we use observations of the same phenomena of previous authors but use different methods and measures of establishing relationships. The difference is that we allow for a non-monotonic supply of crime function whereas most studies impose monotonicity. To ensure meaningful replication we deploy three different data sets from previous studies. The results are interesting in that there is strong support for the use of non-monotonic forms on the original data.

* I am grateful for the comments of an anonymous referee which have improved the presentation considerably.
II. The Economics of Crime Supply

GARY BECKER (1968) outlined a research program for economists that spawned a host of empirical estimates of the effect of punishment and its probability on crime. The Becker approach simply applied standard micro theory to the decision over engaging in crime. Thus it is assumed that criminals are rational utility maximizers. The supply of criminal activity represents the outcome of an optimal choice, under risk, subject to exogenously given constraints. The utility function is of the Von Neumann-Morgenstern type:

$$EU = p \cdot U(Y-f) + (1-p) \cdot U(Y)$$

where $EU$ = expected utility,
$U$ = utility,
$Y$ = wealth if not captured and punished,
$f$ = the loss of wealth if captured and punished,
and $p$ = the probability of capture and punishment.

Wealth is allocated over crime and legal activity according to the values of the above variables and the returns to legal activity. By differentiating (1) with respect to $p$ and $f$ Becker concludes that increases in certainty ($p$) and severity ($f$) of punishment will lead to a reduction in the supply of crimes. Empirical work [see CAMERON (1988)] has often found that these conclusions are not substantiated i.e. a positive or null response to $p$ and $f$ have been obtained. Numerous reasons for this have been suggested. DICKENS (1986) puts forward a "cognitive dissonance" theory although more conventional explanations such as income effects greater than substitution effects; risk in legal work, and the acquisition of crime relevant human capital in prison are available.

The crime supply function is usually operationalised through the assumption of constant elasticity functional forms which include a variety of measures of $p$ and $f$ and additional control variables. The usual measures of $p$ are arrest or conviction rates. The $f$ variable is usually proxied by a measure of the expected length of prison sentence. Controls are
included to hold constant the relative returns in legal and illegal activity. Typical variables to perform this function are measures of income, race, poverty, unemployment and population density.

The supply function is often embedded in a system of equations which endogenizes $p$. The value of $p$ is regarded as the dependent variable in a police production function which contains measures of police input, the crime rate plus controls. The crime rate is included on the grounds that its increase will raise the workload of the police forces who will thus be less able to apprehend criminals. In some studies police inputs are included directly in the supply function. This may be dictated by the absence of suitable data for police outputs. Where this is not the case the inclusion of input measures alongside output measures (such as arrest rates) is presumably an attempt to capture the subjective dimension of criminal's assessment of risk.

In optimistic mood, Gordon TULLOCK (1974) saw fit to inform us that:
"Most economists who give serious thought to the problem of crime immediately come to the conclusion that punishment will indeed deter crime. The reason is perfectly simple; Demand curves slope downward. If you increase the cost of committing a crime there will be fewer crimes" [p. 129 of ANDREANO & SIEGFRIED (1980)].

In the second edition of the New world of Economics (1978) McKenzie and Tullock repeat this point in connection with testing for the existence of deterrence; they then leave out the first edition bibliography on this because "the volume of evidence is so overwhelming that merely listing it would take up too much space" (ibid. p. 139).

This conviction that additional law enforcement always deters is based on the assumption of a monotonic, in particular, upward-sloping supply curve for crime. There are many reasons within neoclassical microeconomic theory why we should not expect to find a monotonic crime supply curve [see CAMERON (1988)] yet all of the considerable volume of economic research on crime constrains criminal supply curves to be monotonic.
It should be noted that Tullock tries to avoid consideration of non-monotonicity by using a demand, rather than supply, analogy for the modelling of crime. His remark might strike a chord with the reader who reasons that the demand curve is negatively sloped because income and substitution effects go in the same direction. In the case of supply curves income and substitution effects are of opposite sign. It should be clear that criminal behaviour is just a form of labour supply as it is a use of time which is rival to legitimate work or leisure.

It follows that finding a significant deterrent effect in data constrained to be monotonic does not prove that deterrence automatically follows increases in law enforcement. Backward or forward bending supply curves contain segments where additional deterrent effort increases the supply of crime. The purpose of this study is to replicate some earlier work on crime using the same data as the authors with the possibility of bending supply curves allowed into the regressions. Three studies are chosen here; the seminal work of EHRlich (1973), and the papers of McPHETERS (1976) and CAMERON (1986). The latter are chosen because the first provides a contrast to Ehrlich in using time-series data for which a more reliable measure of the gain from crime than income is used and the second has a measure of criminal activity which is free from recording bias.

Moving to non-monotonic supply curves raises some problems in estimation. The major problem is that most of the regressors in crime supply functions are simply components of the expected return indeed they are usually proxies for such components. The bending supply curve should thus really bend with respect to the expected return which raises difficulties of how we impose this on its components. We have taken the pragmatic approach of allowing non-monotonicity for the variables chosen by the authors as the primary influences, in their data, on criminal behavior. The remaining variables are thus regarded as controlling for 'tastes' and/or the decision-making environment.
III. McPheters (1976) Re-Estimated

Using an aggregate data time series for the United States of 13 years, 1959-1971, Lee McPheters estimates a log-linear model with the dependent variable being per capita property crime (O) and the independent being reported losses from crime (G), the conviction probability (P) and the arrest probability (R). The innovation in this study is the use of an actual measure of the expected monetary 'take' from a crime in the form of G. Other studies generally use the somewhat inadequate proxy of average or median income expected negative signs on coefficients of P and R as these correspond to p and f in equation (1). A positive sign was expected for the G variable on the assumption of an upward sloping supply curve i.e. the greater the 'wage rate' in crime the greater will be the amount of crime. Statistically significant negative coefficients were obtained for all three explanatory variables. Thus although confirmatory results are found for the risk and punishment variables the response to expected return is anomalous. The anomaly is rationalized in terms of 'target income' levels pursued by satisficing criminals.

It could be argued that this explanation involves inconsistency. Given an uncertain environment a model in which a target level of income is aimed at must be interpreted in terms of aiming at the expected value of the target. It follows from this that an increase in the probability of conviction, if caught, decreases the expected level of income. To attain the target leisure would have to be foregone and more crimes committed implying a positive response to P.

We re-estimated McPheters original function obtaining fairly similar results. OLS estimation was used as in the initial study. On pragmatic (degrees of freedom) grounds we allowed a non-monotonic response only to the variable which was the principle interest of the study namely G. As the original function was \( O = A G^{\beta_1} R^{\beta_2} p^{\beta_3} \) it would not have sufficed to add G squared to the equation as this would still be a monotonic supply function so the form
\[ \hat{O} = 728.5 - 0.5 \, P - 4.7 \, R - 3.5 \, G + 0.0064 \, G^2 \]

\[ (3.93) \quad (0.51) \quad (3.04) \quad (2.13) \quad (1.81) \quad \bar{R}^2 = 0.92 \]

where the figures in parentheses are absolute 't' ratios. The coefficient on G squared is almost significant at the 10% level so there is some support for a backward bending supply curve. The 'F' version of Ramsey's specification test for functional form is \( F(1,7) = 0.2752 \) suggesting that the linear formulation is not a misspecification.

IV. Cameron (1986) Re-Estimated

Cameron (1986) uses 1981 data for 41 police force areas of England and Wales. The dependent variable is per capita malicious false fire alarm calls [MALP]. This is a form of criminal activity that is self-recording therefore it should be free of a spurious association with law enforcement due to the tendency for the proportion of crime recorded to rise when enforcement is increased. The explanatory variables are the percentage of the population male aged 15-24 (YOUTH), the unemployment rate (UNEMP), population density (DENSE), and police officers per capita (POL).

The use of single equation estimation method (OLS) is justified on the grounds that the crime considered is a small part of the total workload of the police. It is not likely that the volume of policing is expanded in response to malicious false fire alarm calls. As explained above the POL variable is substituted for the outputs of arrest, conviction and punishment
that may result from the police production function. The other variables are controls for the relative costs and benefits of the delinquent activity compared with other activities. On the basis of a simple Becker model a negative coefficient would be expected on the POL variable.

The coefficient on POL was strongly significant and positive. In a subsequent paper [CAMERON (1987)] the linear form was shown to be preferable to the log-linear. As the main focus in this study was on the POL variable we add this squared (SQPOL) to the regression and leave the other variables as they were. As in the original paper estimation was by OLS. The results of this exercise are as follows:

\[
\begin{align*}
\text{M\text{\textasciitilde}LP} &= 4.01 + 19.3 \text{ YOUTH} + 0.03 \text{ UNEMP} \\
&\quad (1.73) \quad (2.51) \quad \quad (2.28) \\
&- 0.0005 \text{ DENSE} - 69.15 \text{ POL} + 187.8 \text{ SQPOL} \\
&\quad (0.04) \quad (3.61) \quad \quad (4.27) \quad \quad \bar{R}^2 = 0.85
\end{align*}
\]

where figures in parentheses are absolute 't' ratios.
Here there is clear evidence of a \textit{backward bending} supply curve.

V. Ehrlich (1973) Re-Estimated

Ehrlich's work has been replicated by VANDAELE (1978) and WADYCKI & BALKIN (1979). The data used here is that provided by Vandaele which is corrected for mistakes in the original. Estimates are provided for the supply of burglary, robbery, larceny and auto-theft. The basic Ehrlich model regresses the per capita values of these on proxies for the severity (T, median prison sentence length) and certainty (P, the probability of conviction) plus four additional variables: U, the unemployment rate, W, median household income, X, percentage of households in poverty and NW, percentage of the population non-white. The data used here is for 47 states in the continental United States for 1960.
Ehrlich's model is basically that of Becker (1968). It was thus hypothesized that P and T would have negative coefficients. This was confirmed in the work of Ehrlich and the replication by Vandaele.

In Ehrlich's original work a wide range of different estimates is displayed although these are all based on log-linear functional forms. Greatest stress is laid on the WLS equations where the weights are based on state population. The use of weights is justified on the grounds of potential heteroscedasticity. It should be noted that Ehrlich thus employs three devices which might all be seen as reducing heteroscedasticity. Firstly the dependent variables are in per capita terms; they are then logged and then weighted by population. The population weight might be justified on the grounds that the aggregate data is grouped data i.e. per capita offenses is the average probability of an individual chosen at random carrying out a crime. This justification only seems valid for the linear formulation. The application of weights to the log-linear function invalidates the large R squareds obtained by Ehrlich and Vandaele as the goodness of fit statistic has no clear meaning with a weighted log dependent variable.

The results reported here are all for equations that are weighted and linear in non-punishment variables. These are shown in Table I. Experiments were carried out allowing bends on both the certainty and severity of punishment variables and on each separately. The equations allowing p bends only were virtually always the most supportive of the 'bend' hypothesis. Only burglary gave significant 't' ratios on both quadratic terms. As can be seen from Table I it yielded a backward bend for the p variable and a forward bend for the f variable. Support for the quadratic in p always generated a bacward-bending supply curve. This was found to be significant for all of the property crimes studied except larceny.

The results for burglary suggest an apparent conflict between the effects of certainty and severity of punishment as we would, presumably, expect a consistent model to exhibit the same response to both. The conflict may be resolved by noting the argument [see e.g. Myers (1983)]
that imprisonment generates incentives to crime other than through income effects. A spell in prison enables the individual to learn crime specific skills and to acquire contacts and information useful in the future pursuit of crime.

VI. Summary and conclusion

Past research on crime supply functions has imposed the constraint of monotonicity. This paper has replicated three previous studies with an extension to a quadratic functional form. The results are not clear cut. Some of the evidence suggests a forward-bending supply curve whilst other suggests a backward bend. This may be due to specific properties of individual data sets.

It would clearly be invalid to make sweeping policy conclusions on the basis of this work. However it may provide some interesting speculation. If the supply curve bends forwards or backwards there is the possibility that crime could be reduced by decreasing law enforcement. This will arise if we are on the negatively sloped region of a backward bending curve or of a forward bending supply curve. Either outcome has the same broad implication that, in some cases, the best method of reducing crime may be to reduce the volume of law enforcement rather than increase it.

For the economist who finds these strange conclusions, it must be stressed that crime reduction is not necessarily compatible with efficiency. We can expand on this point with the aid of Figure 1 which shows a forward bending supply curve of crime. The y-axis shows net returns which should decline when there is an increase in law enforcement activity ceteris paribus. The IC schedules are community indifference curves. These have a positive slope because an increase in the supply of crime is a bad but an increase in net returns (holding the level of crime constant) is a good. This follows from the fact that increasing net returns by decreasing law enforcement activity means a saving in resources. The efficient solution is at point O. Clearly the authorities may choose an inefficient
solution such as B where there is too little crime or A where there is too much crime. It is obvious in this case that where decision-makers behave efficiently criminals will never be on the backward sloping part of their supply curve because it is always possible to increase welfare by moving up it. In the real world there is no compunction on decision-makers to behave efficiently as citizen-voters may not have complete information and/or control over their elected representatives. It is thus possible that a point such as B might be chosen where there is too little crime and too much expenditure on deterrence. At such a point any attempt to reduce crime by increasing law enforcement will lead to more crime and a loss in social welfare.

References


McPHERTERS, L.R., 1976, Criminal Behavior and the Gains from Crime. Criminology 14 (1) 137-152.


TULLOCK, G., 1974, Does Punishment Deter Crime? The Public Interest 14 (1) 103-111.

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