A mathematical model on the role of social interactions in crime behavior

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ABSTRACT

The problem of crime is a major issue faced by all mankind. Mathematical models are useful tools which contribute to the field of criminology. The increasing variance of crime rates across space and time is one of the oldest confusion in the sociological perspectives. In this paper we shall discuss a model to explain the spatial variations of crime between and within urban area with the help of social interactions mechanism. This mechanism specifies that an individual is more likely to commit crime if his friends commit than if they do not commit crime. This model is shown to have strong statistical support.

Key Words:

Criminology, variance, social interactions, spatio- temporal.

1. Introduction

In recent decades, the problem of crime is a major issue faced by all mankind. In India, research in criminology is very much neglected among social sciences despite accelerating increase of crime and violence which pose a great threat to our nations. To obtain perfect solutions to the uncertainties of crime in a diverse society claim the application of many disciplines.

The large variance of crime rates across space due to social interactions is a remarkable confusion in the social sciences. These spatial variations of crime behaviour are higher in urban area than rural area of world. According to the 1971 census in India (see S. Venu Gopal Rao) 96 cities with population of 41.4 millions reported 229,860 crimes the Indian panel code. Correlating this figure to the entire urban population of 109 millions, it is estimated that the incidence of crime in urban areas would be in the region of 605,187 constituting nearly 63.5% of the crime in the country. It displays that crime in India follows the familiar in developed countries like United States, Japan, and Sweden etc. This indicates that increasing trend of crime behavior in all these countries is urban –oriented.

Bearse (1996) shows that crime rate is highly concentrated within central urban area. He estimated that crime rates are much higher in the central urban than the suburban in United States. He interpreted that crime victimizations averaged 0.409 per household in central urban during the year 1985 and 1992, where as they averaged 0.306 per household

in suburban areas. Moreover the homicide rate in United State urban is five times greater than that in the suburban (Wllis *et. al.* 2000).

More generally, United States' metropolitan areas have higher crime and unemployment rates, higher population densities and larger relative black populations than their corresponding suburban areas (South and crowder, 1997).

Why do crime rates vary so much over space?

Positive covariance across individuals' decisions about crime is only explanation for variance in crime rates higher than the variance predicted by the differences in local conditions. When one individuals' decision to commit a crime positively affects his neighbors' decision to become a criminal, then urban crime rates will differ from the rates predicted by the urban characteristics, and those crime rates will differ substantially across space(or location) (see Glaeser *et. al.* 1996).

These social interactions occur more in urban than the rural areas, that is why the crime rates are vary much in urban than the rural areas.

The main aim of this paper is a humble attempt to discuss a statistical analysis of crime and its spatial variations due to the social interactions.

2. Review of related literatures

Crime rates have increased dramatically in many countries of world in general and in western countries in particular. A very large literature has developed on the general causes on crime. A growing literature has argued that many economic actions- crimes, education choice, labor force participation are marked by social interactions (Akerlof, 1997, Becker 1997, Bernheim, 1994, Young, 1997). These social interactions imply that the net private benefits from pursuing a particular activity rise as others also pursue this activity. For example, a labor will work hard if his friends also do so for more earning. These interactions can take either in positive or in negative form.

The modern economics literature on crime essentially follows from G.S.Beckers'(1968) model of rational criminal activity. In this model, individuals in the market for crime are assumed to act according to the rules of optimizing behavior. It takes into consideration the pecuniary gain and loss the criminal as well as his victim and the special costs in prevention, law enforcement, adjudication and custodial care of the offender. He also interpreted the probability of arrest of criminal and the quantum of punishments is variable and manipulated in such a manner that the loss to society prevented by the criminal justice system is optimum.

Another economics literature on crime has developed by Isaac Ehrlich (1973, 1975, and 1976). His model is based on the hypothesis that criminal activity is related to the complexities of production and consumption, demand and supply and loss and gain. The choice of criminality is determined by three factors pecuniary reward, available range of alternatives and 'taste'. His models show that criminals tend to decrease their criminal activity only when the probability of capture is increased. Enhancement of punishments may have some limited and marginal effect on the crime level. He also termed the non-economic crimes like homicide and rape as 'psychic income'.

Glaeser,Sacerdote and Scheinkman(1995, 1996) has developed models on crime and social interactions. Their models suggest that social interactions create enough covariance across individuals to explain the high cross-city variance of crime rates. These models display a natural index of social interactions to identify the degree of social interactions across crimes, space and time. These models further estimated that the amount of social interactions are highest in crimes like larceny and auto theft, moderate in crimes such as assault, burglary and robbery and almost negligible in murder and rape.

Glaeser and Scheinkman (1997) presented a model almost similar to the Glaeser *et. al.*(1996) model with a slight extension. They presented the model on measuring social interactions with local interactions but using a continuous action space and starting with optimizing behavior. Futher, Glaeser *et. al.*(2002) has developed an interesting model on the social multiplier . They presented the size of the social multiplier in the impact of education on wages, the impact of demographics on crime and group membership among Dartmouth roommates, where there is a significant social multiplier.

Calvo-Armengo and Zenou (2003), in their social networks and crime decisions model, show that younger agents may benefit each other in their crime business. They show that tentative identical agents connected through a network can end up with very different equilibrium outcomes; either employed or isolated criminal or criminals in networks.

Moreover family adult behaviors are strongly related to analogous youth behaviors. The relation between adult agents and younger agents' behaviors are important for criminal activity. The behaviors of peers appear to substantially affect younger agents' behaviors.

Residence in crime hot spots is associated with a substantial increase in an individual's probability of being involved in crime (see Case and Katz, 1991)

3. The basic model

This model is almost similar to the model of Glaeser *et. al*.(1996) and Zenou on crime and social interactions. Social interactions state that individuals' decisions are influenced by their friends' or neighbors' or peers' decisions. An agent is more likely to commit crime if his peers commit than if they do not commit crime. These models appear to explain spatial variations of crime behavior.

Related literature shows that there are high spatio-temporal variations in crime rate between and within urban. Glaeser *et. al*.(1996) explained that less than 30% of the spatial variations of crime can be explained by differences in local situations and remaining 70% can be explained by social interactions.

Their model can be explained with a society (urban) consisting only two types of individuals or agents say, X and Y. Let the criminal type individuals are denoted by C.

First, suppose the society is without social interactions:

In this society, four possible cases arise-(i) both agents X and Y are criminal (2 types of individuals are criminal) (ii) X and Y both are non- criminal (no individuals are criminal) (iii) X is criminal but Y is not so (1 type of individuals are criminal). (iv) Y is criminal but X is not so (1 type of individuals are criminal). If X and Y decide to be a criminals by tossing a coin (probability ½), then each case occurs with probability 1/4.

So the Expected value of Criminals (C) is as

E(C) = (1/4) (2) + (1/4) (0) + (1/4) (1) + (1/4) (1) =1

And the variance of the criminal is given by

$$V(C) = (1/4)(2-1)^2 + (1/4)(0-1)^2 + (1/4)(1-1)^2 + (1/4)(1-1)^2 = 1/2$$

Now assume that there exist social interactions mechanism in the same society considered above.

Let us consider that there are only two types of individuals say T_1 and T_2 in the society.

In this case only T_1 takes the decision to become a criminal while T_2 imitates T_1. Thus T_2 is influenced by the activity of T_1. Again if T_1 has no propensity to commit crime, then T_2 also has no propensity to commit crime. Hence both individuals have the same kind of propensity, either to commit crime or not to commit crime.

Consequently, a symmetric imitation is occurred between the individuals in the given society due to the social interactions (see Glaeser *et. al*. 1996).

In this case (where social interaction mechanism exist) we have estimated the expected numbers and variance for criminals (C) as –

E(C) = (1/2) (2) + (1/2) (0) = 1

And $V(C) = (1/2)(2-1)^2 + (1/2)(0-1)^2 = 1$

Now from the above estimations, it is clear that both the mechanisms (i.e. without social interactions and social interactions) have the same expected number but different variance. Thus the social interactions model has a higher variance (two times) than the variance of the model without social interactions.

Generalizations of the model:

Let us assume a society having 'n' individuals out of which C_1 are criminal and remaining (n-C_1) are non-criminal.

If there are no social interactions then these two types of individuals (C_1 and (n- C_1)) are considered to be fixed agents. Each individuals C_1 and (n- C_1) takes decision independently for any action. In this case nobody is influenced by others. In this model variance of the criminal C_1 is given by

V (C_1) = n p (1-p), where p= C_1 /n is the probability that a randomly chosen individual is a criminal.

When social interactions are considered where crime decisions are not independent and there is an imitation among the individuals of the society.

We assume a society consisting 'n' individuals of three types say, C_0 , C_1 and C_2 so that

$n = C_0 + C_1 + C_2$, where C_0 are non-criminals, C_1 are criminals and C_2 individuals prefer to imitate their predecessors. C_2 Type of individuals is marginal enough in their decision to become a criminal that they will be moved slowly from side to side by their neighbors' decision.

Each C_0 with positive probability p_0 and C_1 with positive probability p_1 are fixed individuals. These two types of individuals can never be influenced by the actions of their neighbors or friends or peers. The proportion of the fixed individuals in the society (urban) is denoted as π and defined as $\pi = p_0 + p_1$ with $p_0 = C_0 / n$ and $p_1 = C_1 / n$.

The individuals of the type C_2 have the propensity to imitate their neighbors or peers.

Each individual follows the behavior chosen by his predecessors. The sequence of C_2 individuals that are uninterrupted by C_0 or C_1 will imitate the action of C_1 or C_0 that began the sequence. Considering same type of society having three types of individuals in a city, Glaeser *et. al. (*1996) estimated the variance of criminal as

V (criminal) =n p (1-p) f (π)

Therefore, we can write in our model, the variance of the criminal C_1 as-

V (C_1) = n p (1-p) f (π)

Where, $\pi = C_0 / n + C_1 / n$, the probability that a randomly chosen individual is not someone that imitates the others and

$f(\pi) = (2 - \pi) / \pi$, represents the covariance across individuals and captures the degree of imitation.

If no individuals C_2 are present, then π =1, f (π) =1 and V (C_1) = n p (1-p), this indicates that there is no imitation and that means no social interactions occur.

When $\pi \to 0$ (as the probability that each individuals C_2 approaches to zero), f (π) and

V (C_1) both $\to \infty$. Then each and every individual are imitating the others because individual's crime decisions are interdependent. As a result the variance becomes infinite if the proportion of the fixed individuals (π) of the society (urban) approaches to vanish.

This model shows that as f (π) increases, individuals are largely influenced by others and the variance of crime rates rises. The model helps us to explain the spatial variations in crime between and within urban area.

Social interactions increase the effects of crime and if these interactions are localized, then, it becomes easy to explain very high level of crime in some urban area (O'Reagan *et. al* .1993 & Topa 2001). In some urban crime hot spots, criminal acts are spreading like a infectious disease. This is the consequences of the delinquent behavior and peer effects of crime. Hence individuals' behavior is converted by the peer influences of crime which may have social multiplier effects through a feedback loop (Becker and Murphy 2000, Glaeser *et. al* . 2002, manski 1993), that is, more crime based society accelerates more negative social behavior. If this behavior is localized, then it is more considerable. Therefore, it is very essential task to measure the local size of social multiplier in crime for the nation's policy makers. A high social multiplier leads to increasing effects of crime and an individuals' density should not be increased to same crime based area where repeatedly same kind of crime occurs.

4. **Statistical support**

The model has some statistical significance. Indian criminal statistics (rough computations) indicates that crime in urban setting makes up about 63.5% of the total crime in the country, although only 20% of the country's population lives in urban. (See S. V. Rao). In United States the crime rates more in urban by 27% than that of rural (Glaeser *et. al*.1999). These suggest that crime is urban-oriented in most of the countries of world. Glaeser *et. al* .(1999) also show that the probability to be arrested and to be recognized of crime in cities is 20% and the 45%-60% left by the observable characteristics of individuals. Glaeser *et, al* .(1996) estimated crime data nation wise, urban wise and local city wise and reflect that less than 30% of the variation in cross- city or cross- precinct crime rates can be explained by differences in local area attributes. The fundamental explanation that there is a positive covariance across agents' decisions about crime is that the variance of crime rate is higher than the variance predicted by differences in local conditions.

For the justification of the observed cross-city variance, Glaeser *et. al* .(1996) interpreted f (π) , the covariance across individuals and captures the degree of imitation that is index of social interactions between individuals. They estimated crime data for the year 1970 and 1985 across United States cities and for the year 1985 across New York precincts. They have found that the average clique size for serious crimes as 377.They estimated clique size for larceny and auto theft are 221 and 191 respectively. They have found the average clique sizes for robbery, burglary and assault are 78,118 and 112 respectively. They also have shown that the average clique sizes for murder and for rape are 2 and 7 respectively.

Thus they interpreted high intensity of social interactions for larceny and auto theft, a moderate intensity of social interactions for assault, burglary and robbery and very low levels of social interactions for murder and rape.

We discussed that youth criminals are more likely to act peer groups they are more influenced by their friends. Thus youth people display high intensity of social interactions. Some serious crimes committed by the female-headed households have high degrees of social interactions.

Case and Katz (1991) used peer group background characteristics as instruments for peer group outcomes, which in certain cases yields valid estimates of social interactions. They have found some evidence that peer behavior influences self-reported juvenile crime.

5. **Conclusion**

In this paper we have discussed a model to explain the role of social interactions for increasing the spatial variation of criminal activity. First, we consider a simple society with two types of individuals. We show that the estimated crime variations under social interaction is exactly double than the crime variations in the society where no social interactions allowed. Secondly, the generalization of the model have given rise the same result as that there is a high variance of criminal activity across space due to the social interactions. The model helps us to explain the spatial variations in crime between and within urban area.

This model provides us to explain the proportion of potential (fixed) criminals who are not influenced by social interactions. Some empirical works of different authors in this field are discussed for justifying the observed variance of cross-city crime rates. Across crime, it is seen that youth crime behaviors have more social interactions. For serious crimes across cities, the higher degrees of social interactions are found with more female headed households.

We should introduce such type of social interactions technique through which we will forbid any negative social behaviors.

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