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Mathematical Model of Crime and Unemployment

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***Abstract*:- In this paper, we are interested in possible contribution of mathematical modeling of crime. The concentration of criminal activities is not proportional in every area. Because criminal activities depend on socio-economic factors like population densities, unemployment, literacy rate, per capita income, schedule castes and schedule tribes etc. There is a correlation between the volume of crime and these socio-economic factors. The equation of the line of regression is established to interpret the nature of relationship between crimes and unemployment.**

Keywords: Volume of crime, Correlation, Regression

INTRODUCTION

This is the simplest mathematical model which can be applied in many cases where relationship among variables actually exists. As for example, the relationship between the number of criminal convictions and the number of unemployed in a particular span of time in a society can be established.

Similarly, volume of crime and literacy, volume of crime and scheduled castes and tribes and volume of crime and per capita income in a certain area also exhibit some relationship.

The above relationship can be expressed in the form of an equation connecting the dependent variable *Y* and one independent variable *X*. More precisely, the equation takes the form

$$Y = C + BX \qquad (1)$$

This is called the simplest regression equation, where C and B are said to be the regression coefficients.

Similarly, if more than one variable are considered then the regression equation can take another form. In particular, we already know that criminal activities are somewhat related with population density, per capita income, literacy rate, unemployment and proportion of scheduled castes and tribes *etc*.

Then the regression equation takes the following form:-

$$Y = C + B_1X_1 - B_2X_2 - B_3X_3 + B_4X_4 + B_5X_5 \qquad (2)$$

Where Y =Volume of crime per million population
X_1 = Population density;
X_2 = Per capita income;
X_3 = Literacy rate;
X_4 = Unemployment;
X_5 = Percentage of scheduled castes and tribes;

and C and B_i's are regression coefficients.

It is remarkable that the negative sign before the third and fourth terms in relation (2) indicates that the volume of crime reduces for increase of per capita income and literacy rate. Hence there is a negative relationship.

Per capita income and literacy have apparently an inverse relation (negative relation) with crime which suggests that as income levels and literacy rise, crime tends to decrease. The hypothesis is supported to the extent that the bulk of reported crime can be traced to the economically deprived sections and the illiterate on whom the full impact of law-enforcement is felt. It does not necessarily absolve the affluent and the literate from criminality which may assume more subtle forms which do not form part of Penal Code and also have the capacity to defy conventional law-enforcement [7]. On the other hand, unemployment has significantly positive correlation with crime, followed by population density. Although not very significant, the percentage of scheduled castes and tribes appears to have some positive relationship. The marginal significance of this factor can be ascribed to the fairly uniform proportion of this segment in all states. The relationship between the major socio-economic variables hold good for nearly high percentage of crime under the Indian Penal Code and establishes unemployment as the most significant criminogenic factor.

The above equation no. (2) suggests that the relationship between two variables is such as a change in one variable results in a positive or negative change in the other, also greater change in one variable results in a corresponding greater change in the other, is known as correlation.

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LITERATURE REVIEW

The modern mathematical model on crime was initiated by G.S.Becker's model of rational criminal activity[1]. Becker assumed a social loss function which includes costs and benefits of crime. Its minimization determines how many resources and how much punishment should be used to enforce the law.

Isaac Ehrlich developed a model where crime as considered as goods and individuals make rational decisions in the market of crime with a hypothesis- a person commits a crime if his expected utility exceeds the utility he could get with legal activities [2][3][4].

Cambel et al. offer a differential methodological approach to the process by which crime rates changes over time [5]. Their approaches is similar that used in mathematical biology to describe how potential epidemics are either spread or contained in a population [8] . Cambel at al. considered the criminal activity as an epidemic problem. They described the dynamic of the crime rate growth by some differential equations.

Another model describing the interaction of three sociological species, termed as Owners, Criminals and Security Guards [6].In this model [Juan C. Nuno et al.] Criminal is the predator for the species Owners and Security Guards is the predator for the species Criminals. On the basis of pre-predator model they propose a system of three ordinary differential equations to account for the dynamics of Owners, Criminals and Security Guards.

Some modeler tried to relate crime rates to possible explicative variables through linear regressions [9]. The models assume that crime rate = f(explicative variables), where f(.) is a linear function and the explicative variables considered as average income, gender inequality, age, education level, race etc.

Preliminaries

(i) If x and y are two random variables then the correlation coefficients between x and y is denoted by r or r_{xy} and is defined by

$$r = \frac{\sum x_i y_i - \frac{\sum x_i \sum y_i}{N}}{\sqrt{\sum x_i^2 - \frac{\left(\sum x_i\right)^2}{N}}\sqrt{\sum y_i^2 - \frac{\left(\sum y_i\right)^2}{N}}}$$

where, $-1 < r < 1$, r has not units and is a mere number

If $r = 1$, then there exist a perfect and positive correlation between the variables x and y. if $r = -1$, then there exist a perfect and negative correlation between the variables, x and y. The above relation is known as **Karl Pearson's correlation coefficients**.

(ii) The equation of the line of regression of y over x is

$$y - \bar{y} = r\frac{\sigma_y}{\sigma_x}(x - \bar{x})$$

Similarly, the equation of the line of regression of x over y is

$$x - \bar{x} = r\frac{\sigma_x}{\sigma_y}\left(y - \bar{y}\right)$$

where $\bar{x}$ and $\bar{y}$ are the means of the values of x and y respectively. These two relations are known as **Equation of line of regressions.**

We have already discussed that the criminal activities are related with several factors such as population density, per capita income, literacy rate, unemployment etc.

These factors can be correlated positively or negatively or partially with the help of the regression equation (2).

We can apply these mathematical or statistical concepts for the analysis of crime pattern.

Relationship between crime and unemployment

The figure in the following Table- 1 gives the number of unemployed and volume of crime in the states of India for the year 1971. We have to find out the coefficient of correlation for the given data. Also we shall find the equation of the line of regression to interpret the nature of relationship between crime and unemployment.

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Volume of crime and number of unemployment of India, 1971

Table -1

Sl. No.	Name of States	Number of Unemployed = X (Per Thousand Population)	Volume of Crime (Per One Lakh Population)
1	Andhra Pradesh	336	106
2	Orissa	135	138
3	Karnataka	270	124
4	Tamil Nadu	459	144
5	Bihar	420	147
6	Uttar Pradesh	531	166
7	Gujarat	171	121
8	Maharashtra	430	195
9	Assam	789	175
10	Kerala	357	139
11	West Bengal	868	176
12	Haryana	100	82
13	Punjab	118	84
14	Rajasthan	139	142
15	Madhya Pradesh	315	211
16	Himachal Pradesh	45	73
17	Jammu & Kashmir	25	119
18	Tripura	30	114
19	Manipur	38	180

Source:

1. Crime in India,Ministry of Home Affairs, New Delhi
2. Statistical Abstracts, Central Statistical Organization, Government of India, New Delhi.
3. Labour Bureau, Government of India.

Table -2
Calculation for correlation coefficient

Sl. No.	No. of Unemployment = X			Volume of Crime = Y (Per One Lakh Population)			
	x	u	u^2	y	v	v^2	uv
1	336	-21	441	106	-33	1089	693
2	135	-222	49284	138	-1	1	222
3	270	-87	7569	124	-15	225	1305
4	459	102	10404	144	5	25	510
5	420	63	3969	147	8	64	504
6	531	174	30276	166	27	729	4698
7	171	-186	34596	121	-18	324	3348
8	430	73	5329	195	56	3136	4088
9	789	432	186624	175	36	1296	15552
10	357	0	0	139	0	0	0
11	868	511	261121	176	37	1369	18907
12	100	-257	66049	82	-57	3249	14649
13	118	-239	57121	84	-55	3025	13145
14	139	-218	47524	142	3	9	-654
15	315	-42	1764	211	72	5184	-3024
16	45	-312	97344	73	-66	4356	20592
17	25	-332	110224	119	-20	400	6640
18	30	-327	106929	114	-25	625	8175
19	38	-319	101761	180	41	1681	-13079
		$\sum u = -1207$	$\sum u^2 = 1078329$		$\sum v = -5$	$\sum v^2 = 26787$	$\sum uv = 96271$

Correlation coefficients

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$$r = \frac{\sum uv - \frac{\sum u \sum v}{n}}{\sqrt{\sum u^2 - \frac{(\sum u)^2}{n}}\sqrt{\sum v^2 - \frac{(\sum v)^2}{n}}}$$

$$= \frac{96271 - \frac{(-1207)\times(-5)}{19}}{\sqrt{1078329 - \frac{(-1207)^2}{19}}\sqrt{26787 - \frac{(-5)^2}{19}}} \cong 0.586$$

Now, Regression coefficient of x on y = $b_{xy} = r\frac{\sigma_x}{\sigma_y} = r\frac{\sigma_u}{\sigma_v}$

$$= \frac{\sum uv - \frac{(\sum u)(\sum v)}{n}}{\sum v^2 - \frac{(\sum v)^2}{n}} \cong 3.58$$

Similarly, Regression coefficient of y on x

$$= b_{yx} = r\frac{\sigma_y}{\sigma_x} = r\frac{\sigma_v}{\sigma_u}$$

$$= \frac{\sum uv - \frac{(\sum u)(\sum v)}{n}}{\sum u^2 - \frac{(\sum u)^2}{n}} \cong 0.096 \cong 0.10$$

Now, the equation to the line of regression of x over y is

$$x - \bar{x} = r\frac{\sigma_x}{\sigma_y}(y - \bar{y})$$

$$\Rightarrow x - \bar{x} = 3.58(y - \bar{y}) \quad (3)$$

Arithmetic average of unemployment

$$\bar{x} = \text{assumed average} + \frac{\sum u}{n}$$

$$= 357 + \frac{-1207}{19} = 293.47$$

and Arithmatic average of volume of crime

$$\bar{y} = \text{assumed average} + \frac{\sum v}{n} = 139 + \frac{-5}{19} = 138.74$$

So the equation (2.3) becomes

$$x - 293.47 = 3.58(y - 138.74)$$

$$\Rightarrow x = -203.22 + 3.58y \quad (4)$$

and the equation to the line of Regression of y over x is

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$$y - \bar{y} = r\frac{\sigma_y}{\sigma_x}(x - \bar{x})$$

$$\Rightarrow \quad y - 138.74 = 0.10(x - 293.47)$$

$$\Rightarrow \quad y = 109.39 + 0.10x \qquad (5)$$

These two regression equations show that as the unemployment increases the volume of crime also increases.

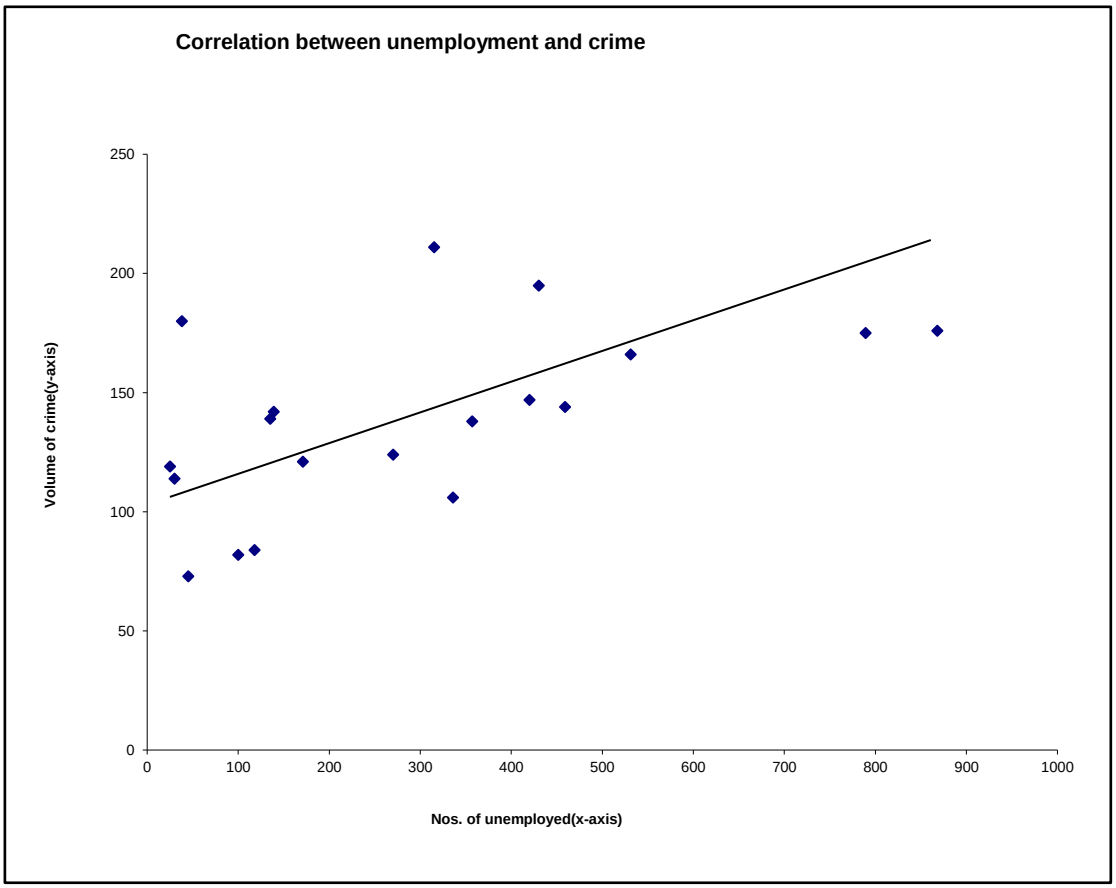

Fig. -1 Correlation between unemployment and crime

Fig. -1 Shows $r > 0$ for standard data given in the Table -1

The Fig.-1 exhibits that as unemployment increases the volume of crime also increases.

CONCLUSION

The positive correlation coefficient $r > 0$ shows that, the volume of crime increases as the unemployment increases. The two equations of regression (4) and (5) represent straight line which exhibit that as unemployment increases the volume of crime also increases. The Fig.-1 also exhibits the same interpretation**.**

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