Determinants of Crime Incidence in Korea: A Mixed GWR Approach [*]

SeongWoo Lee[**]

Seoul National University

DongWoo Kang

Seoul National University

MiYoung Kim

Seoul National University

Abstract: It is true that crime is not exclusively an urban phenomenon, however, most crime and violence occur in cities and urbanized area. The present study investigated the determinants of crime incidence in Seoul city, focusing particularly on spatial and environmental effects on crime victimization. Since crime incidence is in general closely related to the spatial characteristics of a city, we adopted a geographically weighted regression model to incorporate these area characteristics in our statistical model. We also applied mixed GWR model in order to identify local and global effects of independent variables on crime incidence. The results of the model proved to be superior to those from standard spatial econometrics models (SAR, SEM, SAC) with respect to model fits and stability of the parameters estimated. We found that spatial dependency and spatial heterogeneity is particularly important in examining the crime incidence in Seoul. That is, crime in Seoul is primarily spatial; an area is more likely to be victimized by somewhere of the same city than somewhere of another area. Districts with frequent mobility and entertainment spot are more prone to violence and less safe than other districts. Also included among the determinants that contribute to crime incidence are density, size, proportion of youth age group, etc. Zoning is a particularly important factor to determine crime incidence in Seoul. The higher the proportion of residential- and greenbelt-area in an area, the less the incidence of crime likely happens in the area. The present study concludes with some policy suggestions that can alleviate crime incidence focusing particularly on urban planning perspectives.

Key words: Seoul, crime determinants, urban planning, spatial econometrics models, mixed GWR

---

[*] This paper has been prepared for the presentation at the World Conference of the Spatial Econometrics Association, Barcelona, Spain, July 8-10, 2009. This version is a preliminary draft and not ready for citation.

[**] Corresponding author, Professor, Program in Regional Information, Seoul National University, Seoul, Korea, 151-921, E-mail: seonglee@snu.ac.kr, TEL: 82-2-880-4744, CP: 82-10-7646-2429

I. Introduction

Seoul, the capital city of Korea, has a special meaning for most people in Korea. Seoul has always been a Mecca for those who live outside it since Yi dynasty in the 15th century. It is true that Korea relies heavily on the CR in almost every social and economic aspect. Occupying about 12% of the country's total area in 2005, the Seoul metropolitan area (hereafter Seoul) held 46.3% of the total population. In addition to the share of the population, most widely cited statistics for the Seoul dominance over the rest of the country are 48% of GRDP (gross regional domestic product) to the nation's GNP, 57% of manufacturing firms, 72.3% of total R&D companies, 88% of the headquarters of major large enterprises, 68% of deposits, 65% of total loan amount, 85% of total public administrative offices and 40.7% of universities. The CR also accounts for 62.7% of R&D expenditure, 72.3% of the venture capital companies and 65.8.9% of Korea's printing establishments producing newspapers and magazines.

Its dominance is even more pronounced in terms of fiscal resources, accounting for 71% of personal income tax receipts and 85% of corporate income tax receipts in 2003. Average per capita local tax revenue in the capital region is more than 60% above the national average, resulting in wide regional variations in the share of own-source revenue in local government revenue (Randall & Tadashi, 2005). Seoul and its surrounding areas, the center of government, education, culture, industry and entertainment, is truly the heart of Korea and the perception of 'Seoul and other dessert' prevails in the country. However, the excessive concentration of the nation's life - in politics, economics and culture - in Seoul has caused a large number of urban problems, including housing, transportation and environmental degradation and so has crime victimization.

Such an excessive concentration in urban region makes a lot of undesirable side effects such as pollution, poverty, and housing problems. Especially, most metropolitan cities have recently been suffered from crime in common which has become more cruel, diversified, and intelligent. It is said that urban crime reflects gap of ability to gain spatially limited resources and spatial reactions caused by disadvantages confronted with poor environment (Herbert, 1977). Furthermore, damages from crime and fear of being a victim have been recognized as one of urban diseconomy that impedes urban development. Accordingly, the realm of criminology has been widened toward preventing urban diseconomy as well as searching characteristics of crime and criminals.

In Korea, incidence of crime in Seoul is higher than that of other region. In Seoul, with as much as a fifth of the total population of Korea, there were 382,833 crime incidences in 2003, about a fifth of the total crime of Korea. According to a survey by Korean National Statistics

Office, about two thirds of inhabitants of Seoul (63%) have indefinable fear of crime, and it is referred as major reason of residential dissatisfaction in Seoul.

Previous studies on crime deal with causes and effects of crime from various aspects. Series of studies based on social organization theory suggest that different social features between regions make different types of crime. Criminal opportunity theory focuses on potential opportunities that happen to induce crime rather than investigating criminals itself. Strain theory argues that unsuccessful people can easily commit crime because of relative deprivation and frustration at their situation. Literatures of economics of crime emphasize individuals' rational choice based on benefit and cost analysis.

This paper is organized as follows: Section II introduces the mainstreams of previous criminological studies. Section III explains variables and spatial econometric analysis method adapted in our model. In section IV, we provide the empirical results of our estimation. Section V summarizes our findings and suggests several policy implications.

II. Background

A great deal of public attention has been focused on the problems of crime in urban regions. Crime, as a deviant behavior, has been a latent but strong threat against humanities long before, and it has became a major social issue since the 1960s (Blau and Blau, 1982). Recently, crime is considered as a case of diseconomies which can reduce the utility of the whole society and impede proper urban growth.

Criminology as a field of science had its beginnings in Europe in the late 1700s in the writings of various philosophers, physical scientist, sociologists, and social scientists. Most of the major developments in modern criminology, however, took place in the United States, which was closely linked with the development of sociology (Hagan, 1986). Group of scholars with the Chicago school argued that human activity was affected not by genetic factors but by social and physical environment, which provide human community with cultural values and definition dominating people's activity. Especially, the works of Shaw and Mckay who studied crime and delinquency in Chicago in 1920s with mapping have a great influence on establishing the basis of criminology. Despite of its sociological roots, criminology, as an interdisciplinary study, has now become one of the major subjects for researchers of various fields such as urban planning, architecture, public administration, and so forth.

Early studies by Shaw and Mckay, called as 'social disorganization theory', emphasize that the cause of crime and misdemeanor is determined by regional ecology. From this perspective, low economics status, heterogeneity, and residential mobility are social factors that impede the ability of communities to generate an effective system of institutional control. In series of their researches, they showed that the high crime rate areas in Chicago in 1900-1906 were also the high rate areas in 1917 and 1923, although the ethnic composition of these areas had, in the meantime, largely been transformed. According to their studies, Chicago had developed into a series of five concentric zones, with some marked by wealth and luxury, while others were characterized by overcrowding, poor health, poor sanitation, and extreme poverty. They saw that more delinquency offenses occurred in the transitional inner-city zones of the city than in others. They concluded that these slum areas were the spawning grounds for delinquency due to weak social control (Ebbe, 1989). To reduce crime rate, they thought residents must try to restore communities' social organizations with self-supportive activities and improve economic conditions. Shaw and Mckay's approaches are highly esteemed for establishing an ecological basis of modern criminology and still utilized for analyzing crime. In following studies consistent with the social disorganization theory, lower economic status, ethnic heterogeneity, high residential mobility, family disruption, weaker social networks, and lower community organization are usually associated with higher crime rates across various geographical units.

Since the 1970s, Cohen and associates have argued that changes in routine activity patterns of everyday life can increase crime rates even if these social forces that enhance criminal inclinations remain constant (Miethe et al., 1991). From this perspective, changes in leisure and sustenance activities provide an opportunity structure for predatory crimes by increasing the contact between potential victims and offenders in time and space.

The three conditions explaining criminal opportunity theories are exposure to crime, target attractiveness, and guardianship. Exposure to crime refers to a target's visibility and accessibility to risky situations and locales and is typically measured by the level and nature of non-household activity. Target attractiveness is defined in terms of both its material and symbolic value to offenders but tends to be measured by various economic indicators (e.g., GNP, median income, expenditures on durable consumer goods). Guardianship refers to the ability of persons or objects to prevent the occurrence of crime and is usually represented by the number of housemates and the level of crime-protection activities (e.g., police expenditures, security alarms, and door locks). According to a criminal opportunity perspective, changes in conventional activities increase crime rates because they increase exposure to motivated offenders, enhance target attractiveness, or decrease the level of guardianship. What makes criminal opportunity theory interesting is that it suggests that we can account for crime without having to focus on why people commit illegal acts. Assuming a nonzero level of criminal motivation, variability in crime is explained by variation in structural conditions that create opportunities for its occurrence. Crimes occur because people or goods are exposed, unguarded, and viewed as attractive targets, not just because social structure and significant others motivate people to commit crimes, fail to direct people to noncriminal pursuits, or provide inadequate socialization experiences. Thus, criminal opportunity is not a theory of criminal motivation that explains how variation in social structure allows criminal motivations to be expressed more easily (Miethe et al., 1991). Many studies from the opportunity theory conclude that measures of expenditure to crime (e.g., nighttime leisure activity, nonhousehold activity) are positively related to crime rates and individuals' risks of victimization. Safety precautions and other types of guardianship have a deterrent effect in most studies, but the impact of target attractiveness is less conclusive.

Strain theory, suggested by Merton (1938), argues that when faced with the relative success of others around them, unsuccessful individuals feel frustration at their situation. The greater the inequality, the higher this strain and the greater inducement for low-status individuals to commit crime (Kelly, 2000). Blau and Blau (1982) noted that higher inequality between races made higher crime rate of the southern regions of US, using strain theory (Kelly, 2000).

In the economic theory of crime, Becker, Ehrlich and others depend on expected utility models as their theoretical framework, not on sociological theories. Becker (1968) assumes that an individual, as a rational utility maximizer, has a tendency to abandon criminal behaviors if he or she does not choose risk-loving activities under uncertainty with the possibility of punishment and cost. Persons commit crime only when the benefit from crime outweighs the cost of crime. Ehrlich (1968) thinks individuals allocate time between market and criminal activity by comparing the expected return from each, and taking account of the likelihood and severity of punishment (Kelly, 2000).

Space is considered as one of the most important factors in latest criminological study. This trend, called environmental criminology, focuses on crime itself and its surroundings, rather than on criminals' features and conditions that make them commit crime. Brantingham (1981) explains that crime is composed of laws, criminals, targets, and places and their mutual reactions. Brown (1982) studies on spatial distribution patterns of crime with spatial autocorrelation effects analysis. GIS analysis and other mapping analysis on crime have been published and tried to examine regional effects of crime.

<Table 1> presents diverse empirical studies regarding crime incidence from diverse geographical settings. There are some variations in selecting independent variable, theoretical backgrounds explained are quite similar to this section. While some studies use micro/individual data, most studies use macro/aggregated data for their crime studies. I also found that more recently, spatial econometrics techniques are adopted but no study ever adopts mixed GWR model to identify crime determinants and geographical context upon crime incidence.

Table 1. Literature Review about Crime Incidence

Articles	Methodology	Dep. Vars.	Indep. Vars.
Roncek and Maier (1991)	OLS / Tobit Model	The Number of Crime Event	Percentages primary individuals(+), Percentages female-headed families(+), Percentage over 60(-), Percentage 18-60(+), Percentage black(-), Heterogeneity(+), Percent Spanish(-), Housing value(+), Percentage overcrowded,(+) Percentage multiunit(+), Vacancy(+), Residential Population(+), area(+), Population potential(+)
Ackerman (1998)	OLS	Crime Rate	Race/weak family structure(+), Economic marginalization(+), Population(+), Human capital deficiency(+), Youth(+)
Smith, Frazee et al. (2000)	Multiple Regression / 2 Stage Least Squares	The Number of Street Robbery Incidents per Face Block	Population(-), Single-parent households(-), Distance from Center(-), Number of African Americans(-), Racial heterogeneity(-), Percentage of buildings in low quartile of value(-), Average value of buildings(-), Numbers of Motel/Hotels(+), Number of stores(+), Number of Bars/ restaurants/gas stations(+), Number of vacant or parking lots(+), number of multifamily residential(-), Number of owner occupied(-)
Ceccato, Haining et al. (2002)	OLS / Spatial Error Model	The Number of Bugarly, Vandalism, and Automobile Theft	Percentage born abroad(+), Percentage unemployed aged 25-64(+), Average income(+), Percentage immigrated(-),Percentage multifamily(+)
Cahill and Mulligan (2003)	OLS	Crime Rate / The Number of Crime	Racial heterogeneity(+), Percentage with B.A.(-), Percentage renter occupied(+), Population density(-), Percentage of total population below

		Event	the poverty level(+), Percentage 5year or more lived resident(+), Percentage of vacant housing(+)
Lee and Cho (2006)	Spatial Econometrics	Crime Rate	Property tax per person(-), Residential Population(-), Population density(-), Commuting population(+), Percentage aged 15-24(+), Percentage of high educated people(-), Numbers of yellow entertainment(+), Numbers of Policemen(-), Percentage of green belt(-), Percentage of residential area(-), Percentage of lodging and restaurant area(+)
Andressen (2006)	Spatial Error Model	The Rate of Automobile Theft, Break and Enter, and Violent Crime	Unemployment rate(+), Population change(+), Single parent(-), population(-), Population density(-), Number of dwellings(+), Average income(+), Youth population(-), Percentage rental(-)
Kim (2007)	Bayesian Hierarchical Model	The Number of Residential Crime	Poverty(+), Residential Stability(-), Crime opportunity(-)
Cahill and Mulligan (2007)	OLS / GWR	Log of Crime Rate	Concentration at the extremes(+), Light-rail stop(+), Married families(-), Multiple land use(+), Population density(-), Residential stability(-), Single-person household(+)
Chun and Park (2008)	OLS, SAR, CAR	Log of Property Crime	Age 13-17(-), Percentage black(+), Percentage Hispanic(-), Homeownership(-), Unemployment(+), Average income(-), Commercial density(+)

In Korea, it is not difficult to find crime studies based on sociological basis but the regional crime approaches are hardly found because of inaccessibility to basic crime data. Choi and Jin (1999) try to examine relation between regional characteristics and crime rate with longitudinal and cross-sectional analysis. They note that the number of entertainment spots is one of the major factors of increasing violent crime, and the crime rate of small cities is higher than rural and metropolitan areas because of higher population influx. Choi (2003) studies spatial distribution of crime in Seoul using GIS mapping analysis, showing that areas adjacent to commercial district or entertainment spots have higher crime rate than other areas.

III. Data and Methodology

III-1. Data and Variables

In this section, we outline the data on crime, socio-economic variables, urban planning variables and weight matrix used in estimating the following regression.

Our crime data are taken from the 2003 Seoul Crime Reports, which contain information on aggregate crime, five major crimes (homicide, robbery, rape, assault, and larceny), and intellectual crime.

Socio-economic variables—such as proportion of youth, proportion of highly educated, the number of settled population, population density—are drawn from 2000 Korea Census Data (2% sample). The number of policemen and that of entertainment establishments are taken from the internal data collected by Seoul Metropolitan Police Agency (SMPA), while property tax per household and the number of floating population are obtained from Seoul Metropolitan Government Data. We utilize urban planning variables such as proportion of limited development district, proportion of houses' building floor area, proportion of accommodations' building floor area, which are compiled by Seoul Development Institute. Each independent variables and descriptions are denoted in Table 2. Except proportion of highly educated, which is collected in 2000, all of the other variables are collected in 2003.

We hypothesize the effect of each independent variable on crime as follows. Based on previous criminological studies, property tax per household is likely to have a negative effect on crime in that heavier taxpayer seems to have relatively higher schooling and live in the safer facilities. Property crimes, such as larceny and intellectual crime, however, show a tendency to increase in higher tax-paying regions (McDonald, 1997).

Population stability is a good measure of predicting crimes because population mobility reduces the cohesion of communities (Kelly, 2000). In our regression model, we assume that the number of crime decreases as the number of settled population increases. The number of floating population, however, tends to augment regional crimes by increasing the possibility of being a victim.

Age has a close correlation with crime. The youths around 20 years of age, in general, show the highest crime rates, while those of thirties become peak in Korea (Kim and Lee, 2001).

Young people, age 15 to 24, tend to commit larceny and robbery, but violence and fraud are committed by adult offenders. Therefore, the proportion of youths has different impacts by categories of crimes.

Table 2. *Variable Description*

Variable		Description	Mean	S.D.
Dependent Variable				
Crime rate		Log counts of crime per 100,000 individuals	8.37	0.56
Independent Variable				
Socio-economic Variable				
	TAX	Property tax per household (KRW)	0.17	0.31
	DEN	The number of settled population	0.17	0.07
	FLOW	The number of floating population	0.57	0.41
	YOU	Proportion of youth aged from 15 to 24	27.82	3.42
	EDU	Proportion of university graduate	0.31	0.12
	POL	The number of policemen	5.20	2.11
Urban Planning Variable				
	GBT	Proportion of limited development area	23.64	19.71
	RES	Proportion of residential area	37.46	22.40
	SER	Proportion of accommodation area	1.50	1.67
Weight Matrix				
W		Standardized first-order Rook continuity matrix		

College education is measured by the percentage of population with 4 year or more of college education, which reflects the relation between poverty or economic opportunities and crime. The possibilities of crimes become lower between persons with higher education career.

Based on social disorganization theory, since there can exist more potential offenders in the fleshpots, the number of entertainment establishments has positive correlation with crime. The number of policemen in a certain region is thought as a constraint to prevent crimes.

While we can hardly find the correlation between urban planning variables and crime in previous studies, we can roughly expect the effect of each variable on previous studies. We assume that there happen fewer crimes in the region of higher rate of limited development district, considering that most crimes generally take place in more urbanized regions. Major crimes, such as homicide or robbery, however, can be committed in unfrequented areas.

Residential areas are measured by the rates of houses' building floor areas. Most theories see that the possibilities to expose crime sharply reduce, while property crime, such as larceny is expected to increase in residential areas. On the contrary, the rates of accommodations' building floor areas—positively related to floating population—possibly increase a region's crime rates.

III-2. Spatial Econometrics Models

III-2-1. Mixed GWR

Following Brundson et al. (1996), GWR(Geographically Weighted Regression) model can be defined as

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{m} \beta_k(u_i, v_i)x_{ik} + \varepsilon_i, \quad i = 1,2,\cdots,n \tag{1}$$

y_i : ith dependent variable

(u_i, v_i) : Location in the studied geographical region

β_0 : coefficient of intercept

β_{ik} : coefficients of independent variables

X_{ik} : independent variables

ε_i : error term ($\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$)

Then, the vector of coefficient at (u_i, v_i) is estimated by

$$\hat{\beta}(u_i, v_i) = [X^T W(u_i, v_i) X]^T W(u_i, v_i) Y \tag{2}$$

$\hat{\beta}(u_i, v_i)$: estimated coefficients of location (u_i, v_i)

$X = \begin{pmatrix} 1 & x_{11} & \cdots & x_{1m} \\ 1 & x_{21} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & \cdots & x_{nm} \end{pmatrix}$: nx(m+1) independent variables matrix

$Y = (y_1, y_2, \cdots y_n)^T$: nx1 dependent variables matrix

$W(u_i, v_i) = \mathrm{diag}\{(w_1(u_i, v_i), w_2(u_i, v_i), \cdots, w_n(u_i, v_i)\}$: nxn diagonal matrix

There are several ways to determine $W(u_i, v_i)$ like Bi-square, Exponential, Tri-cube, and Gaussian , etc., the present study selects exponential function shown in Eq. (3)

$$w_j(u_i, v_i) = \sqrt{e^{-d_{ij}/\theta}} \tag{3}$$

d_{ij} : distance between location (u_i, v_i) and (u_j, v_j).

Following Cleveland(1979), the present study applies Eq. (4) to minimize bandwidth parameter θ shown as following.

$$\Delta(\theta)=\frac{1}{n}\sum_{i=1}^{n}[y_i - \hat{y}_i(\theta)]^2 \qquad (4)$$

The GWR model in Eq. (1) can be expressed as in Eq. (5), a mixed GWR version suggested by Brunsdon et al. (1996).

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{l}\beta_k x_{ik} + \sum_{k=l+1}^{m}\beta_{ik}(u_i, v_i)x_{ik} + \varepsilon_i \qquad (5)$$

Where, β_k(1,…,l)s are global coefficient

β_{ik}(l+1,…,m)s are local coefficient

Eq.(5) can be expressed as the following matrix notation,

$$\mathbf{Y} = \mathbf{X}_G\boldsymbol{\beta}_G + \mathbf{m} + \boldsymbol{\varepsilon} \qquad (6)$$

$\mathbf{Y} = (y_1, y_2, \cdots, y_n)^T$

$\boldsymbol{\beta}_G$: vector of global coefficients

X_G : independent variables matrix of global coefficients

$\mathbf{m} = \sum_{k=l+1}^{m}\beta_{ik}(u_i, v_i)x_{ik}$

Assuming that $\boldsymbol{\beta}_G$ is known, we could use basic GWR procedure to estimate $\mathbf{m}$

$$\hat{\mathbf{m}} = \mathbf{L}(\mathbf{Y} - \mathbf{X}_G\boldsymbol{\beta}_G) \qquad (7)$$

$$\mathbf{L} = \begin{pmatrix} \mathbf{x}_1^T[\mathbf{X}^T\mathbf{W}(u_1, v_1)\mathbf{X}]^{-1}\mathbf{X}^T\mathbf{W}(u_1, v_1) \\ \mathbf{x}_2^T[\mathbf{X}^T\mathbf{W}(u_2, v_2)\mathbf{X}]^{-1}\mathbf{X}^T\mathbf{W}(u_2, v_2) \\ \vdots \\ \mathbf{x}_n^T[\mathbf{X}^T\mathbf{W}(u_n, v_n)\mathbf{X}]^{-1}\mathbf{X}^T\mathbf{W}(u_n, v_n) \end{pmatrix}$$

Thus, the global coefficients are defined as

$$\hat{\boldsymbol{\beta}}_G = [\mathbf{X}_G^T(\mathbf{I}-\mathbf{L})^T(\mathbf{I}-\mathbf{L})\mathbf{X}_G]^{-1}\mathbf{X}_G^T(\mathbf{I}-\mathbf{L})^T(\mathbf{I}-\mathbf{L})\mathbf{Y} \qquad (8)$$

If we apply Eq. (8) to Eq. (7), then we can derive local coefficients.

In general, deriving local coefficients has been dependent upon researchers' insights, recently Mei et al.(2004) argue we need a certain test statistic that can verify the validity of the local and global coefficients. Mei et al.(2004) suggest that before executing the mixed GWR model, the coefficient $\beta_k(u_i,v_i)$ for each variable $x_k(k=1,2,\cdots,m)$ can be estimated by the basic GWR model in Eq. (1) to identify its role as local or global variable.

If we define the null hypothesis and the alternative hypothesis in Eq. (5) , then

$$\begin{cases} H_0: & \beta_k(u_1,v_1)=\beta_k(u_2,v_2)=\cdots=\beta_k(u_n,v_n), \\ H_1: & \text{the values of } \beta_k(u_i,v_i) \text{ are unequal at least at two different locations.} \end{cases}$$

The test statistic suggested by Mei et al.(2004) is as following.

$$F(k)=\frac{\tilde{\beta}_k^T(I-\frac{1}{n}J)\tilde{\beta}_k}{e^Te}=\frac{Y^TB^T(I-\frac{1}{n}J)BY}{Y^T(I-L)^T(I-L)Y} \tag{9}$$

$\tilde{\beta}_k=(\hat{\beta}_k(u_1,v_1),\hat{\beta}_k(u_2,v_2),\dots,\hat{\beta}_k(u_n,v_n))^T$

J : nxn unity matrix

$e=(e_1,e_2,\dots,e_n)^T$ risidual vector

$$B=\begin{pmatrix} d_{k+1}^T[X^TW(u_1,v_1)X]^{-1}X^TW(u_1,v_1) \\ d_{k+1}^T[X^TW(u_2,v_2)X]^{-1}X^TW(u_2,v_2) \\ \vdots \\ d_{k+1}^T[X^TW(u_i,v_i)X]^{-1}X^TW(u_i,v_i) \end{pmatrix}$$

d_{k+1} : column vector of $m+1$ dimensions with unity and zero for others

Leung et al.(2000a) show that at every *i* , if $\hat{y}_i$ is unbiased for $E(y_i)$ and H_0 is true, then Eq. (9) can be rewritten as the following Eq. (10).

$$F(k)=\frac{\varepsilon^TB^T\left(I-\frac{1}{n}J\right)B\varepsilon}{\varepsilon^T(I-L)^T(I-L)\varepsilon}=\frac{\varepsilon^TM_1\varepsilon}{\varepsilon^TM_2\varepsilon} \tag{10}$$

$$\begin{cases} M_1=B^T\left(I-\frac{1}{n}J\right)B \\ M_2=(I-L)^T(I-L) \end{cases}$$

In Eq.(10), M_1, $M_2$are two symmetric and positive semi-definite $n\times n$ matrices. By Leung et al.(2000a), the statistic (10) is approximately distributed as F-distribution. Thus, the p-value is defined as

$$p(k) = P\left\{\frac{\varepsilon^T M_1 \varepsilon}{\varepsilon^T M_2 \varepsilon} > f(k)\right\} = P\{\varepsilon^T[M_1 - f(k)M_2]\varepsilon > 0\}, \tag{11}$$

where $f(k)$ is the observed value of $F(k)$ which can be computed with a data set given.

Utilizing diverse simulations, Imhof(1961), Tango (1995), Rogerson(1999), and Leung et al. (2000b) proved that quadratic form of any normal variable can be approximated via the three-moment χ^2 approximation which can reduce computational overhead, so Eq.(11) can be expressed by the following Eq. (12).

$$p(k) \approx \begin{cases} P\left\{\chi_d^2 > d - \frac{1}{b}\mathrm{tr}[M_1 - f(k)M_2]\right\}, \text{ if } \mathrm{tr}[M_1 - f(k)M_2]^3 > 0 \\ P\left\{\chi_d^2 < d - \frac{1}{b}\mathrm{tr}[M_1 - f(k)M_2]\right\}, \text{ if } \mathrm{tr}[M_1 - f(k)M_2]^3 < 0 \end{cases} \tag{12}$$

$$\begin{cases} b = \dfrac{\mathrm{tr}[M_1 - f(k)M_2]^3}{\mathrm{tr}[M_1 - f(k)M_2]^2} \\ d = \dfrac{\{\mathrm{tr}[M_1 - f(k)M_2]^2\}^3}{\{\mathrm{tr}[M_1 - f(k)M_2]^3\}^2} \end{cases}$$

Based on the test statistics in Eq. (12), the present study identify global and local coefficients followed by carrying out the mixed GWR model shown in Eq. (5) to Eq. (8). For the comparative purposes, in the next section, the present study adopts traditional spatial econometrics models(SAR, SEM, SAC) in Eq. (13) to Eq. (15).

III-2-2. SAR, SEM, SAC

As stated above, while crime is strongly affected by personal attributes, it has a close correlation with spatial features or regional circumstances. Dependent and independent variables used in our regression model have spatial autocorrelation and spatial dependency, which depreciate parameters' reliability in analyzing spatial data. When analyzing micro-data, multi-level modes are of use; spatial econometrics model are utilized if the data are macro-data (Lee et al, 2004a, 2004b). Since the data in this study are macro-data collected by SMPA, we use three types of spatial econometrics model. We explain these modes as below:

The general form of standard linear regression model which has constant variance of error term is denoted by

$$M = X\beta + \varepsilon$$

where M is an n x 1 vector of crime rate and X is an n x k matrix containing independent variables. Vector β represents a vector of k regression coefficients, and ε is an *iid.* vector of n error term.

In this study, we adapt three types of alternative spatial econometrics models, which can correct spatial dependency. The first model is the spatial autoregressive model (SAR), which assumes that observation that are near should reflect a greater degree of spatial dependence than those more distant from each other(LeSage, 1999).

$$\mathrm{M} = \rho \mathrm{W(M)} + \mathrm{X}\beta + \varepsilon \tag{13}$$

$$\varepsilon \sim N(0, \sigma^2 \mathrm{I}_n)$$

where M is an n x 1 vector of dependent variables and X denotes an n x k matrix of explanatory variables. W represents spatial weight matrix containing contiguity relations or functions of distance. The scalar ρ is a coefficient on the spatially lagged dependent variable, and β denotes a parameter vector estimated from explanatory variables.

The second model we utilize is the spatial autoregressive error model (SEM); it is based on the assumption that the disturbances exhibit spatial dependence.

$$\mathrm{M} = \mathrm{X}\beta + u \tag{14}$$

$$u = \lambda \mathrm{W}u + \varepsilon$$

$$\varepsilon \sim N(0, \sigma^2 \mathrm{I}_n)$$

where the scalar λ is a coefficient on the spatially correlated errors.

The last one used in this study is the general spatial model (SAC) which includes both spatial lag term and a spatially correlated error term.

$$\mathrm{M} = \rho \mathrm{W(M)} + \mathrm{X}\beta + u \tag{15}$$

$$u = \lambda \mathrm{W}u + \varepsilon$$

$$\varepsilon \sim N(0, \sigma^2 \mathrm{I}_n)$$

W shown in model (13), (14), and (15) is the spatial weight matrix, containing contiguity relations or functions of distance. To reflect spatial dependence between adjacent regions, W matrix contains regional information such as latitude and longitude.

$$W_{ij} = \frac{d_{ij}}{\sum_{\substack{j=1 \\ i \neq j}}^{n} d_{ij}} \text{ , where } d_{ij} = 1 \textit{ if connected to j}, \text{ or } 0 \textit{ otherwise} \tag{16}$$

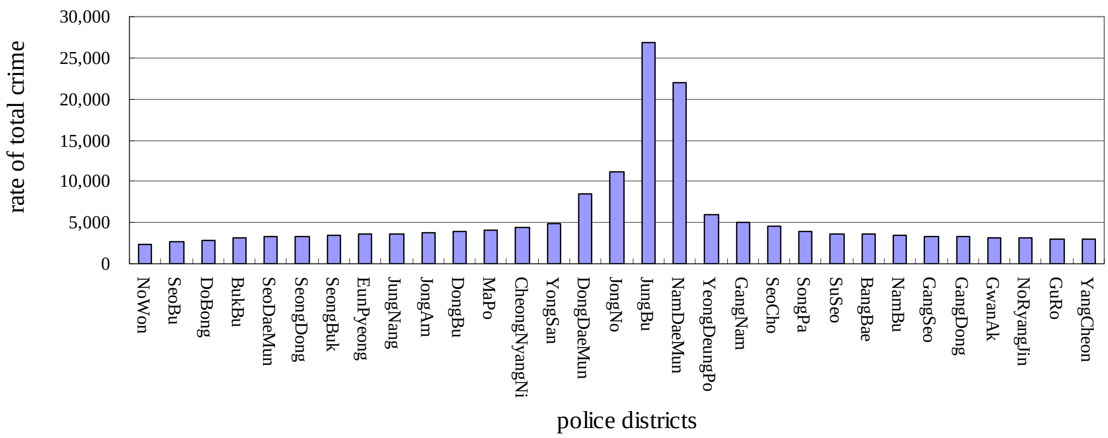
In spatial econometrics model, Equation (16) is referred as SAR(W1) showing AR(1) structure in time-series analysis. Equation (16) is one of the most useful types of weight matrix in previous studies, although it is very simple. In regression of the total crime, the logarithmic transformation of both dependent and explanatory variables is executed to estimate the percentage change in dependent variable for a one percent change in independent variables. Then, linear model is used to estimate determinants of individual crime type.

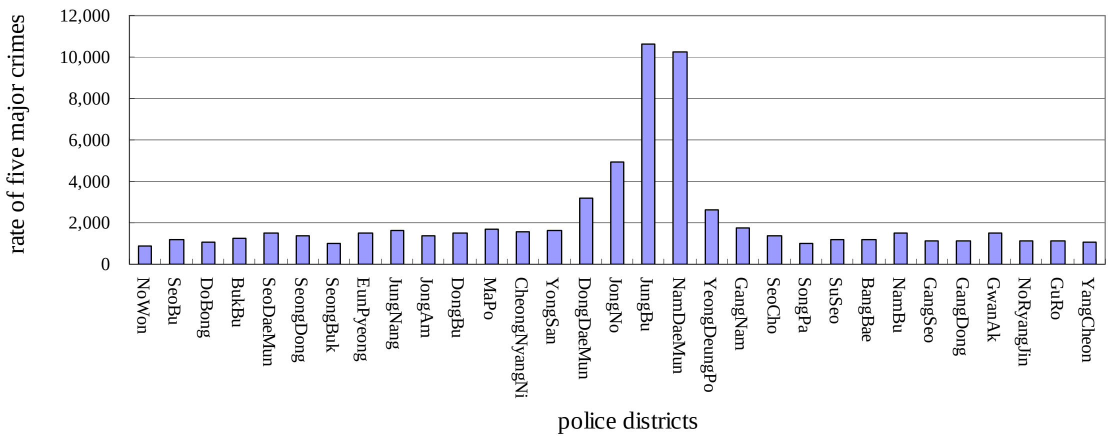
IV. Results

IV-1. Crime Incidence in Seoul Special City

Figure 1 presents rates of total crime and five major crimes per 100,000 inhabitants by police districts of Seoul in 2003. Districts shown in the middle (DongDaeMun, JongNo, JungBu, NamDaeMun) are not only the old center but also the central business district of Seoul. Districts of the left side of the CBD are the northern area of Seoul and they are arranged from the inner to the outer part of the city in general. Districts of the opposite side belong to the southern area and arranged by the same order.

Figure 1. *Rates of Total Crime and Five Major Crimes per 100,000 inhabitants by police districts of Seoul, 2003*





In 2003, there were 382,833 total crime incidences in Seoul. This turns to 3,723 per 100,000 inhabitants. On the whole, the highest total crime occurrence rates were to be found in the CBD of Seoul. The sub-centers, YongSan in the north, and then YeongDeungPo, GangNam and SeoCho in the south, showed the next highest total crime rates, but the difference was considerable. Bedroom communities of the outer Seoul like NoWon, SeoBu, DoBong, and YangCheon showed the lowest total crime incidence rates.

We can see striking contrast of crime incidence rate through spatial characteristics of the city. There were 26,841 total crime incidences per 100,000 inhabitants in JungBu, the police district of the highest crime incidence. The total crime rate of JungBu was 5 times as high as the average of Seoul (5,375 per 10,000 inhabitants). The average number of total crime incidence in sub-centers, however, was only 5,076—accounting for 19% of JungBu’s. The total crime rate per 10,000 inhabitants of bedroom communities was less than 3,000. That rate of NoWon, the police district of the lowest rate, was 2,410, which was 9% of JungBu’s.

Similar tendency was observed in the rates of five major crime incidences. The police districts in CBD showed predominantly higher rates than average. The sub-centers followed next. Then, bedroom communities had the lowest rates. A distant decay pattern of five major crime rates with distance to Seoul was apparent.

Noticeably, most of the crime victimization happened in the center of the city as a general conception. The districts in CBD ranked 1^{st} to 4^{th} in rates of most types of crime. The CBD has high non-resident, day-time populations and relatively small settled populations because of intensive retailing activities, government and non-government offices. Offices and entertainment spots like bars and clubs are also concentrated in the sub-centers. The mobility of population is high in this area as well. The resident population is, however, higher than the CBD. In particular, GangNam and SeoCho are one of the typical residential districts of propertied class. A common knowledge that GangNam and SeoCho are cardinal criminal area is proved, but the crime rates are relatively lower to the CBD.

These socio-economic and residential features of area imply a close relation to crime incidence. The settled population of JungBu and NamDaeMun, the districts of first and second high crime incidence rates, was 22,976 and 22,504 in 2003, respectively. By contrast, the floating population of these two districts was 507,297 and 527,268 respectively, which were larger than the settled population by 22 to 23 times. This proportion is remarkably high considering 2.3 times of Seoul as a whole.

DoBong and YangCheon, two representative residential areas of the north and south Seoul, had the lowest rate of entertainment spots per inhabitants, in 2003. Also, the proportion of floating population to settled population of these two districts ranked 20th and 31st respectively. Therefore, DoBong and YangCheon ranked very low in the rate of several types of crime and total crime. YangCheon ranked lowest in robbery. This is understandable through the fact that the proportion of residential area was about 70% in YangCheon, and 44% of inhabitants were living in apartments.

Crime incidence rates show a spatial difference by an economic level. Classified by property tax, DongBu, GangNam, SeoCho, SongPa and SuSeo ranked in the top five districts and NoWon, SeoBu, EunPyeong, JungNang, and JongAm ranked in the bottom five districts. The total crime and five major crime rates were higher by 32% and 4% respectively in the top five districts than the bottom five districts. Compared to the bottom five districts, the rates of the top five districts were higher by 88% in robbery, 44% in forcible rape, 20% in homicide, 3% in larceny-theft, and 2% in assault and battery. Higher crime occurrence rates were found in the area of greater prosperity. Nevertheless, it is also possible that environmental effects caused this result than economic level. GangNam, SeoCho, SongPa and SuSeo are neighboring districts, and they are the sub-centers of Seoul. These districts have both well-organized residential environment and entertainment establishments that have effect on violence crime. The number of the entertainment facilities was 7,472 in the top five districts and 4,677 in the bottom five districts.

IV-2. Identification of Local/Global Variables

Table 3. Results of Global Coefficient Test

Vars.	Int.	TAX	DEN	EDU	GBT	RED	SER	POL	YOU	FLOW
p-value	0.2951	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1922	0.5398	0.1593
H0	Not Reject	Reject	Reject	Reject	Reject	Reject	Reject	Not Reject	Not Reject	Not Reject
Coeff.	Global	Local	Local	Local	Local	Local	Local	Global	Global	Global

<Table 3> shows the results of global coefficient test incorporating Eq. 12. Among the nine independent variables, I identify six variables as local parameters and three independent variables as global. The first two columns in <Table 4> present the results of standard- and mixed-GWR models. Based on the results, I will analyze determinants and effects of independent variables on crime incidence in Seoul in the following section. The effects of the six identified local independent variables by police districts were depicted in the <Appendix 1>, which shows significant variations for each local parameters on crime incidence by police districts.

IV-3. Determinants of Total Crime Victimization

The results of three standard spatial econometrics models based on Eq. (13), (14), (15) are also estimated. Among all models, the SAC model has the highest adjusted *R*-squared statistic: 0.9627 in the OLS model; 0.9650 in the SAR model; 0.9858 in the SEM model; and 0.9972 in the SAC model. The value of VIF which measures the impact of collinearity among the independent variables in a regression model is smaller than 10 in SAC model.

The results of SEM and SAC estimation show that both spatial autoregressive parameter (rho) and spatial error parameter (lambda) are highly significant, indicating the presence of both types of spatial effects. OLS-based inference, then, is not appropriate for modeling criminal victimization in Seoul. Therefore, the most suitable specification for our data is the SAC model. The following inference is based on the general spatial model estimations.

All variables have their expected effects. Standardized coefficients in OLS estimation indicate the effect of independent variables regardless of their units. The variable with the largest value (positive or negative) has the largest influence on the value of the dependent variable. Thus, settled population (-0.8927), residential area (-0.1925), floating population (0.1918) are the three major determinants of crime victimization in our model.

In the SAC model, almost all of the coefficients are statistically significant at the one percent, five percent or ten percent levels except for the number of police. Using socio-economic variables, we find floating population, proportion of youth, and the number of entertainment spots have positive relation with the total crime victimization. Proportion of accommodation area also has positive sign. Variables which have negative effects on the total crime victimization are property tax, settled population, proportion of youth, and population density.

Table 4. *Estimation Results of Total Crime*

	GWR		Spatial Econometrics Model		
	Standard	Mixed	SAR	SEM	SAC
			coeff.	coeff.	coeff.
Intercept	7.8625 L	G	16.5391 ***	13.4782 ***	11.9196 ***
Socio-economic Variables					
TAX	0.2737 L	L	0.0477	-0.0047	-0.0661 ***
DEN	0.4013 L	L	-1.1211 ***	-0.9185 ***	-0.6938 ***
FLOW	0.5227 L	G	0.3393 ***	0.4525 ***	0.4713 ***
YOU	0.0269 L	G	0.2735	0.8183 **	0.9655 ***
EDU	-0.2525 L	L	-1.0475 *	-1.3863 ***	-1.4107 ***
POL	-0.0741 L	G	-0.0259	-0.0313	-0.1054
Urban Planning Variables					
GBT	-0.0032 L	L	-0.0087 **	-0.0111 ***	-0.0111 ***
RES	-0.0042 L	L	-0.2178 *	-0.2464 ***	-0.3599 ***
SER	0.1434 L	L	0.0372	0.0362	0.0247 *
rho			-0.0440		0.0870 ***
lambda				-0.9999 ***	-2.0515 ***
bandwidth	4.4721	4.4721			
R-squared	0.9764	0.9740	0.9778	0.9910	0.9982
Rbar-squared	0.9627	0.9688	0.9650	0.9858	0.9972
Log-Likelihood			44.7686	43.9574	116.6228

* p<0.1, ** p<0.05, *** p<0.01

Urban planning variables, our main concern, have significant and expected sign. The total crime incidence increases by 2.47 percent for a one percent increase in accommodation area. Conversely, one percent change in limited development area or residential area result 1.11 and 35.99 percent reverse change in total crime victimization, respectively.

V. Conclusions

Crime is a regional phenomenon and therefore mirrors spatial characteristics of a certain region. It is not easy, however, to detect the effects of regional variables on crime. The present study tried to discern local and global effect of each variable on crime incidence in Seoul, Korea. This paper also tries to find out the correlation between crime and spatial features using spatial econometrics, and proposes alternative policies for desirable urban planning. With the cross-sectional data on crime rate and region, I have found that the number of floating population and entertainment establishments strongly affects the increase of crime rate. In SAR and SEM model, the incidence of 5 major felonies can be increased by 29~33 percentage points with 1 percent increase of floating population. Entertainment establishment can bring about the 16~20% increase of 5 major felonies.

Moreover, this study finds that urban planning variables are highly correlated to crime rates. If greenbelt area is increased by 1%, aggregate crime rate can be diminished by 1.1 percentage points. A 1% increase of residential area can lead to a 35.9% decrease of aggregate crime rate. On the contrary, if accommodation building floor area is augmented by 1%, aggregate crime rate can be increased by 2.5%.

The present study has focused on the spatial effects of urban crime incidence and suggested some important implications to urban planners and policymakers. First, greenbelt restriction, if necessary, should be lifted for developing residential area to prevent increase of crime. If the district lift allows people to build up entertainment establishments, aggregate crime rate can possibly soar up. Second, variables related to crime have a close relation to the total numbers of entertainment establishments and accommodations. To reduce crime rates, therefore, commercial districts should be properly controlled by urban planning laws regulating maximum numbers of entertainment establishments and accommodations.

The data of this study provide only one year's crime rate collected by 31 jurisdictions of Seoul Metropolitan Police Agency, which may cause ecological fallacy in our regression results. More detailed information on criminals, zonings, and urban planning policies can allow us to detect clearer effects of such variables on crime.

Stated above, regional characteristics affect clearly the augment of crime incidence. Further studies on the relation between crime and urban planning policies are necessary for crime prevention and safer urban communities. Especially, interdisciplinary researches between criminology and urban planning are essential to prevent crime in urban areas.

Reference

Ackerman, W. (1998). "Socioeconomic correlates of increasing crime rates in smaller communities." The Professional Geographer. **50**(3): 372-387.

Andresen, M. A. (2006). "Crime Measures and the Spatial Analysis of Criminal Activity." Br J Criminol. **46**(2): 258-285.

Beasley, Ronald W., "The Etiology of Urban Crime: An Ecological Analysis, American Society of Criminology", February 1974, Vol. 11(4): 439-461.

Becker, Gary S., "Crime and Punishment: An Economic Approach", The Journal of Political Economy, Mar.-Apr., 1968, Vol. 76(2): 169-217.

Blau, Judith R., and Peter M. Blau, “The Cost of Inequality: Metropolitan Structure and Violent Crime”, American Sociological Review, February 1982, Vol. 47: 114-129.

Brantigham, P.J., and P.L. Brantigham, “Residential Burglary and Urban Form”, Urban Studies, 1975, Vol. 12: 273-284.

Brown, M.A., “Modeling the Spatial Distribution of Suburban Crime”, Economy Geography, 1982, Vol. 58: 247-261.

Cahill, M. and G. Mulligan (2007). "Using Geographically Weighted Regression to Explore Local Crime Patterns." Soc. Sci. Comput. Rev. **25**(2): 174-193.

Cahill, M. and G. Mulligan. (2003). "The Determinants of Crime in Tucson, Arizona." Urban Geography. **24**(7): 582-610.

Ceccato, V., R. Haining, et al. (2002). "Exploring Offence Statistics in Stockholm City Using Spatial Analysis Tools." Annals of the Association of American Geographers. **92**(1): 29-51.

Choi, Hyun-A, A Study on the Spatial Distribution of Urban Crimes with Special Reference to Youngdungpo-Gu of Seoul, in Korean, The Thesis of Master in Urban Planning, Seoul National University, 2003.

Choi, Insub, and Chin Soomyung, Relationship between Regional Characteristics and Crime Rate, in Korean, Korean Institute of Criminology, 1999.

Chun, Y. and Y. Park (2008). "Neighborhood Effects and Spatial Patterns in Irban Crime: A Case Study of the City of Dallas, Texas." Korean Urban and Geography. **11**(1): 85-99.

Cleveland, W., 1979, "Robust locally weighted regression and smoothing scatterplots." Journal of the American Statistical Association. 74: 829-836.

Cohen, Lawrence E., and Marcus Felson, “Social Change and Crime Rate Trends: A Routine Activity Approach”, American Sociological Review, August 1979, Vol. 44: 588-608.

Ebbe, Obi N., “Crime and Delinquency in Metropolitan Lagos: A Study of “Crime and Delinquency Area” Theory”, Social Forces, March 1989, Vol. 67(3): 751-765.

Ehlich, Issac, “Participation in Illegitimate Activities: A Theoretical and Empirical Investigation”, Journal of Political Economy, 1973, Vol. 81: 521-565.

Hagan, Frank E., Introduction to Criminology: Theories, Methods, and Criminal Behavior, Chicago: Nelson-Hall Inc., 1986.

Herbert, David T., and David M. Smith, Social Problems and The city: Geographical Perspective, Oxford: Oxford University Press, 1979.

Imhof, J., 1961. "Computing the Distribution of Quadratic Forms in Normal Variables." Biometrika. 48: 419-426.

Kelly, Morgan, “Inequality and Crime”, The Review of Economics and Statistics, November 2000, Vol. 82(4): 530-539.

Kim, Hyung-Man and Dong-Won Lee, Introduction to Criminology, in Korean, Cheongrok Publishing, 2001.

Kim, Y. (2007). "An analysis of urban economic and social status effects to residential crimes usign Bayesian hierarchical modeling." The Journal of the Korean Urban Geographical Society. **10**: 115-127.

Kim, Young-jun, The Estimation and the Empirical Analysis of Supply of Offences Function, in Korean, The Thesis of Master in Economics, Seoul National University, 2006.

Land, K. C. and M. Felson (1976). "a general framework for building dynamic macro social indicator models: including an analysis of changes in crime rates and police expediture." american journal of sociology. **82**.

Land, K. C., P. L. McCall, et al. (1990). "Structural Covariates of Homicide Rates: Are There Any Invariances across Time and Social Space?" The American Journal of Sociology. **95**(4): 922-963.

Le Sage, James P., The Theory and Plactice of Spatial Econometrics, http://www.econ.utoledo.edu, 1999.

Lee, S. W., J. K. Cho, (2006). "The Effect of Spatial and Environmental Factors on Crime Victimization", Research of Seoul & Other Cities. 7(2): 57-76. (in Korean)

Leung, Y., C. Mei, and W. Zhang. (2000a). "Statistical Tests for Spatial Nonstationarity Based on the Geographically Weighted Regression Model." Environment and Planning A. 32: 9-32

Leung, Y., C. Mei, and W. Zhang. (2000b). "Testing for Spatial Autocorrelation among the Residuals of the Geographically Weighted Regression." Environment and Planning A. 32: 871-890.

McDonald, J.F., Fundamentals of Urban Economics, NJ, USA: Prentice Hill, 1997.

Mei, C., S. He, and K. Fang. (2004). "A Note on the Geographically Weighted Regression Model." Journal of Regional Science. **44**: 143-157.

Merton, Robert, “Social Structure and Anomie”, American Sociological Review, 1938, Vol. 3: 672-682.

Miethe, Terance D., Michael Hughes, and David McDowall, “Social Change and Crime Rates: An Evaluation of Alternative Theoretical Approaches”, Social Forces, September 1991, Vol. 70(1): 165-185.

Rogerson, P., 1999. "The Detection of Clusters Using a Spatial Version of the Chi-Square Goodness-of-Fit Statistics." Geographical Analysis. 31: 130-147.

Roncek, D. W. and P. A. Maier (1991). "Bars, blocks, and crime revised: Linking the theory of routine activities to the empiricism of 'Hot spots'." Criminology. Blackwell Publishing Limited. **29:** 725-753.

Sampson, R. J., S. Raudenbush, et al. (1997). "Neighborhoods and violent Crime: A Multilevel Study of Collective Efficacy." Sicence. **277**: 917-924.

Smith, W. R., S. G. Frazee, et al. (2000). "Furthering the integration of routine activity and social disorganization theories: Small units of analysis and the study of street robbery as a diffusion process." Criminology, Blackwell Publishing Limited. **38:** 489-523.

Stahura, John M., and John J. Sloan III, “Urban Stratification of Places, Routine Activities and Suburban Crime Rates”, Social Forces, June 1988, Vol. 66(4): 1102-1118.

Tango, T., 1995. "A Class of Tests for Detecting ‘General’ and ‘Focused’ Clustering of Rare Disease." Statistics in Medicine. 14: 2323-2334.

Yoon, Ok-Kyung, and Hee-Jong Joo, “A Contextual Analysis of Crime Rates: The Korean Case”, Crime, Law and Social Change, 2005, Vol. 43: 31-55.

Do not quote ((Rupansingha, Anil, and Stephan J. Goetz, “County Amenities and Net Migration”, Draft for the WRSA Annual Meeting, Rio Rico, Arizona, February 26-March 1, 2003.))