

Article

Pattern and Explanation of Inter-City Crime Variation in South Korea

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Abstract: The primary purpose of this paper is to test the applicability of environmental criminology in South Korea. Moreover, it explores effective strategies from a spatial planning perspective by taking control of diverse spatial planning factors. The study area is South Korea, and the base year is 2016. A spatial econometric model is built to analyze the relationship between the built environment and three crimes (theft, violence, and sexual assault). As a result, the best spatial regression models for violent crime rate and sexual assault rate are a spatial error model (SEM) and a spatial autoregressive model (SAC), respectively. The most prominent finding is that the regression results in the three crimes are slightly different. The broken windows effect was negligible for significant crimes in South Korea. The influence of regional disorders on the incidence of crimes was marginal. In the three crime types, mixed land use affected rising crime rates, which aligns with some previous studies that mixed land use increases the likelihood of crime incidences. In contrast with a series of relevant works, brighter nighttime light has not effectively decreased crimes in South Korea. In South Korea, closed-circuit television (CCTV) did not play a role in deterring crimes. Lastly, socio-economic characteristics were closely connected with crime rates in South Korea. The theft rate, violent crime rate, and sexual assault rate confirm the reliability of environmental criminology. Although this study has examined the likelihood of applying environmental criminology, further research and discussions are followed for concrete plans.

Keywords: crime; environmental criminology; spatial regression models; spatial planning; South Korea



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1. Introduction

Why does crime concentrate in smaller areas? Academic efforts to address this question date back to the 19th century when interests in the spatial distribution of crime emerged in France. The spatial distribution of criminals and crime studied by the French government in 1825 is considered the first of its kind [1]. Although the result was not substantial enough, due mainly to the lack of suitable statistical models, the study managed to identify the variability of crime across regions. In the 20th century, research on the spatial distribution of crime started to evolve in earnest. Through pioneering studies, such as the concentric zone model [2] and social disorganization theory [3], crime's spatial characteristics in specific places were identified. In the late 1980s, with advances in computer technology, it was made possible to detect the concentration of crime in micro areas (i.e., crime hot spots) with accuracy [4]. The resulting spatial patterns of crime stirred researchers' interest in the tie between crime and place, eventually leading them to give birth to environmental criminology.

Environmental criminology is a broad concept that crime is closely associated with the environmental conditions of places [5]. This theory focuses on offenders' decision-making process, noting that spatial circumstances can provide offenders with cues or opportunities [6]. This perspective enables proactive criminal prevention through effective control of space because poor performance (inadequate knowledge of attractors, generators, and

crime patterns) of spatial conditions might increase the possibility of crime occurrence [7]. More importantly, proper design and effective use of the built environment can reduce fear of crime and incidence, eventually improving quality of life [8]. Various preceding research have proved the potential and effectiveness of environmental criminology, and the achievement and development of the theory are ongoing [5,9,10]. Ref. [1] divides evolution stages of environmental criminology into four periods: (1) the beginning in Europe in the 19th century; (2) the heyday of the Chicago school of neighborhood research in the first half of the 20th century; (3) spatial research in Canada, Europe, and the United States from the 1980s; and (4) the international focus on the study of crime in smaller spaces in the 21st century. These developmental stages directly inspired this research. The usefulness of environmental criminology should be documented in a broader range of countries to take a step forward, focusing on areas where relevant studies and applications are scarce.

The main contributions of this paper are threefold. First, this study tests the applicability of environmental criminology in the case of South Korea. Second, it explores more effective strategies from a spatial planning perspective by taking control of diverse spatial planning factors. Third, the study identifies standard spatial planning practices that can apply to multiple crime types rather than a specific crime. Further explanation is needed as to why South Korea was chosen as the study area and why it is necessary to consider multiple crime types. In 2005, the Korean National Police Agency (KNPA) announced its plan to enforce environmental criminology, focusing on crime prevention through environmental design (CPTED), a recent hot research topic in the field of public policy [11]. The scope of CPTED is expanding, particularly in aspects of redevelopment, criminal vulnerability, and school zones. In 2014, CPTED-oriented revision was enforced in the national building code and the redevelopment plan. In sum, South Korea has endeavored to embrace environmental criminology.

In analyzing the applicability of environmental criminology, it is required to consider various crime types to achieve generalization [6]. On the policy front, generalized connections between crime and place suggest that generic environmental interventions may be both widely applicable and scalable [12]. We first consider the five major crimes: homicide, robbery, theft, violent crime, and sexual assault. Due to their massive negative impact on society, these crimes are of the highest interest in almost all countries. Given the unique feature of crime occurrences in South Korea and insights from preceding studies, we selected three significant crimes: theft, violent crime, and sexual assault.

2. Theoretical Background

Environmental criminology, recognized as a key strategy for preventing crime, has evolved systematically. Various theories have been established and introduced so far. The relevant studies have examined the core theories, including the concentric zone model, social disorganization theory, routine activity theory, crime pattern theory, broken windows theory, environmental criminology, and CPTED. By looking into the development of environmental criminology, we can find reference points on environmental criminology while establishing a theoretical framework. In particular, the spatial and environmental factors covered in the related works are directly referenced for the selection of variables of regression analysis.

The concentric zone model is a pioneering work that figured out the relationship between crime and space [2]. Although the primary purpose of this creative study was to build a new conceptual framework to explain the complex urban land use with the concentric ring theory, this study illustrated where crime is high and which regional features can lead to a high crime rate. Of the five classified land use zones suggested by the study, the second zone (the transition zone) showed a loss in the sense of community, resulting in large social disorganization, which acted as a mechanism to increase deviant behavior and criminality. The argument that poor neighborhood conditions could impact much more on crime than other factors, such as race and ethnicity, has been supported by a bevy of studies until recently [13].

Social disorganization theory [3], which is mentioned as one of the important theories in criminology, is spatial criminology because it succeeds [2]. They analyzed the causes of higher rates of juvenile delinquency in the transition zone [2] from social disorganization perspectives. The authors thought that social organization or cohesion at the neighborhood level is vital for combating crime. Therefore, neighborhoods lacking voluntary control through social cohesion and integration are more likely to be crime victims. In social disorganization theory, various characteristics of neighborhoods, such as demographic, economic, and spatial contexts, are considered essential factors for understanding crime. The macro approach to social disorganization theory is sometimes criticized [14], but its usefulness and generalizability are proved by many studies [15].

Routine activity theory [16], one of the main sources of environmental criminology, pays attention to the circumstances that can stimulate crime in any given space and time. Crime is presumed to occur when there is a motivated offender, an accessible target, and no guardians to intervene [17]. Some argue that it is possible to curb the chance of crime by leveraging guardians' behaviors. Some believe that with all the above conditions of crime known, the opportunities, trends, and periods of crime occurrence are predictable, informing crime prevention activities. However, the lack of explanation for the connection between criminals and victims, and the lack of the individual's moral beliefs or the strength of social bonds, factors that can suppress crime, are perceived as limitations of routine activity theory [18].

Crime pattern theory focuses on the mechanism of crime [19], which occurs when a victim and a target intersect in a particular space. The theory describes crime moves in space and time by taking three spatial features into account: nodes (place), paths (actual paths), and edges (boundaries of districts). Notably, this theory explained the relationship between space and crime based on human behavioral patterns. Moreover, the idea can help to clarify the spatial concentration of specific crime patterns. Despite the coverage of crime being restricted to the individual level [14], crime pattern theory still holds firmly in environmental criminology on the ground of the various advantages discussed above.

Broken windows theory [20], the most familiar crime theory, also has a vital position in environmental crime. As [20] illustrated, disorder and crime are usually inextricably linked in a developmental sequence. In theory, the broken window is a symbolic expression of disordered space where it is likely to attract crime over time. This concept also includes the spatial spillover effect in crime, in which disorder space causes crime, which gradually extends to neighboring areas. Therefore, efforts to suppress the dangers of disordered space in advance are essential for preventing crime. Besides, the theory shows why policing should be concentrated in neighborhoods that are vulnerable to criminal invasion.

Even if several theories had had a profound effect on environmental criminology, before Brantingham and Brantingham [5,21], environmental criminology existed as fragmented theories. Many agree that they have provided practical implications for improving environmental criminology concepts and applications for a long time since the 1980s. According to Brantingham and Brantingham [22], a crime occurs only when space, time, law, offender, target, and victim come together. Conversely, no crime occurs if one factor that constitutes a crime is missing. In deriving the five factors as reasons for crime, this theory deals with strategies for the physical environment and nature of neighborhood structures. By systematically explaining the connection between land use, traffic patterns, urban design, daily activities, and movements of victims and offenders, environmental criminology contributed to crime prevention. From a spatial planning point of view, these articles are of high value as they provide a theoretical framework for understanding spatial planning roles in curbing crime through land use, transportation, and facility planning, which are the central part of spatial planning. Like other relevant theories, this study also has limitations. Overemphasis on place-based factors and the lack of consideration of the spatial patterns of crime have been limitations of the theory [23].

The last theory needed to review is CPTED. The pioneering concept of this theory is [24]'s defensible space. Newman's ideas on public housing design helped shape envi-

ronmental criminology as a new area of focus in urban housing and accessibility [25]. While Newman's theory focuses on crime prevention activities primarily from an architectural point of view, CPTED aims for a comprehensive approach. In other words, it would design a safe building and place from crime by using a wide range of environmental design elements that can minimize the chance of crime. There is criticism that CPTED is a defense-oriented strategy and ignores crime motives or offenders [23]. However, CPTED has been receiving the most attention in environmental criminology since 2000, and its application has been expanded to developed countries such as the United Kingdom, Australia, the United States, and Singapore due to its successful crime-reduction capability. In South Korea, the study area of this paper, CPTED has been actively implemented in recent years. Its utilization is expected to continue to increase quickly.

The two key takeaways from the theory review are: First, the research areas in space and crime have been greatly expanded and achieved remarkable theoretical development. Given the significant influence of place on crime, the rapid growth of environmental criminology is obvious. Second, previous studies illustrate the usefulness and crucial position of environmental crime. In modern criminology, in which proactive crime prevention activities are recognized, much more importantly, the significant influence of environmental criminology is more likely to be strengthened in the future. The present study aims to complement the existing research in two aspects. To understand crime determinants through the lens of environmental crime, it is necessary to identify the effects of spatial planning factors on crime more comprehensively. The study investigates the possibility of spatial factors for proactive crime prevention strategies. Until now, environmental crime has been active in some developed Western countries. To expand the validity and practicality of environmental crime across the globe, new research should be conducted in countries where relevant research is scarce. The study ascertains the applicability of environmental criminology in South Korea, where the interest in environmental criminology has been low. This effort can contribute to the generalizability of environmental criminology.

3. Study Area

The study area is South Korea, and the base year is 2016. Although it is desirable to use more recent data, securing relevant data as unofficial data on crime occurrence by police jurisdiction in Korea is almost impossible. The data for 2016 are very unusual and confirmed by a media report. The use of historical data that is somewhat far from 2022 may be a limitation of this study. However, the incidence of crime in Korea has not changed significantly from the past until recently. Therefore, for this study focusing on environmental criminology, using data from 2016 is not a limitation. The study area covers almost all of South Korea, except for some islands where there are no reliable materials or where spatial adjacency for spatial regression models is obscure to determine. Using the basic statistics provided by [26], the crime trends in Korea are as follows. As of 2016, 1,849,450 total crimes (3577 crimes per 100,000 population) occurred in South Korea [26]. Over the last ten years (2009–2018), about 1.8 million crimes per year have occurred in South Korea and have maintained the crime trends. From 2014 to 2018, sexual assault rates increased by 12%, while theft and violent crime rates decreased by 34% and 1%, respectively. Given that homicide and robbery rates were also reduced by 13% and 39, respectively, in the same period, sexual assault was the only increase in the five major crimes. Thus, social concerns about sexual assault in South Korea have arisen.

Figure 1 displays the outlines of the study area and geographical distributions of theft, violence, and sexual assault rates (per 10,000 population) in 2016. The study area consists of 216 police districts. Due to the principle of boundary demarcation that considers people's size, the police districts in and near big cities such as Seoul, the capital of South Korea, are smaller than other regions. Figure 1 offers some baseline for our understanding of the distribution of the three crime rates and their variation across districts, as of 2016, 36.5 theft, 55.6 violent crimes, and 5.0 sexual assault occurrences per 10,000 population in the study area [26]. The spatial distribution pattern reveals the differences between the

crime rates. The theft crime rates are relatively high in and surrounding big cities. The two types of crime rates are generally higher in the northern regions than in the southern regions when the study area is divided into two parts (south and north). Examining the link between the three types of crimes with different spatial distributions and environmental criminology can provide critical implications on how to contrive and develop effective crime prevention policies.

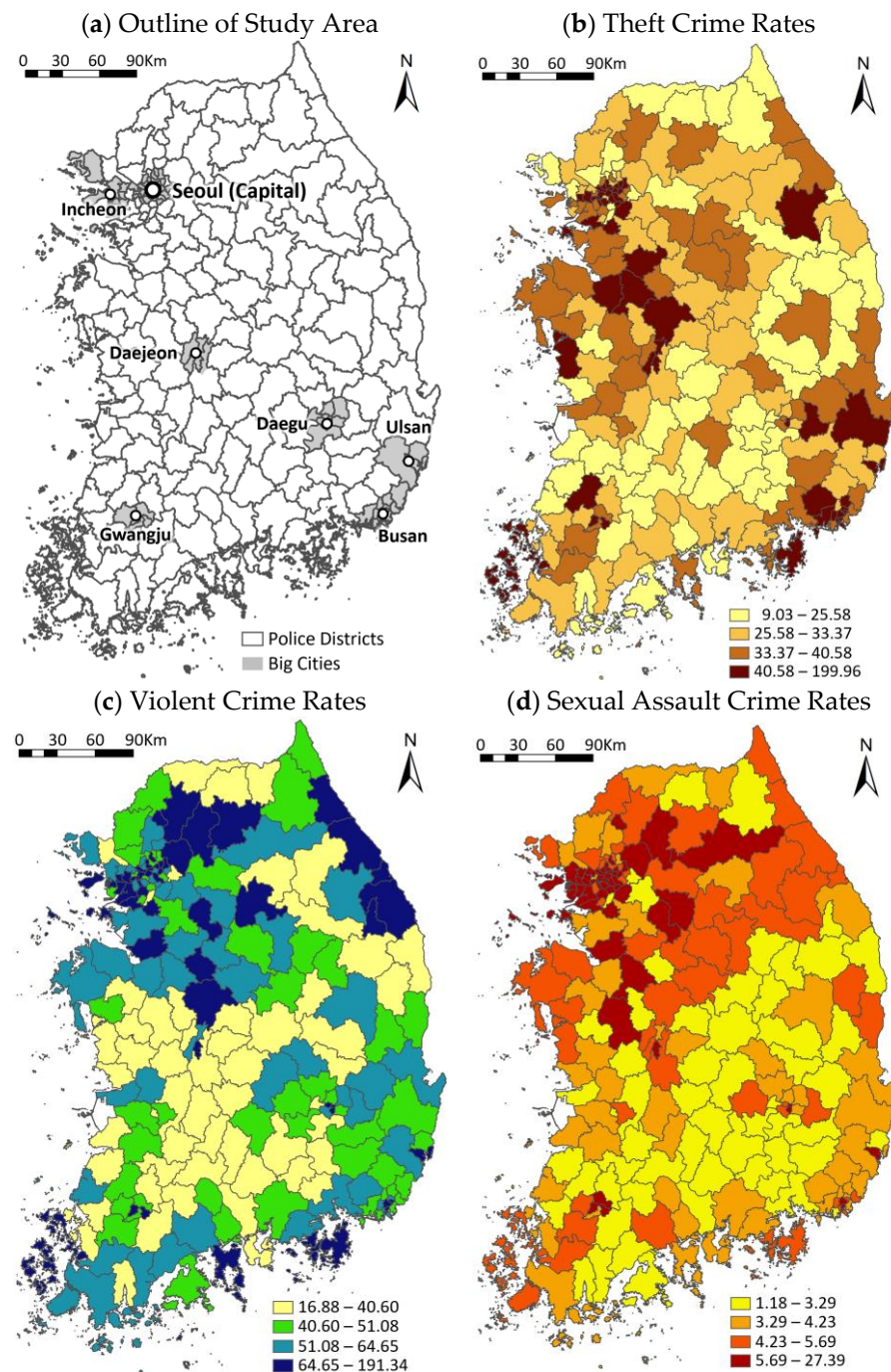


Figure 1. Study Areas and Spatial Distribution of Crime Rates in 2016. Note: Respective crime rates refers to the number of crimes per 10,000 population.

4. Methodology and Variable Selection

4.1. Spatial Regression Models

The classical linear multiple regression models presume that observations or regions are independent. This assumption, however, is often unrealistic. Spatial data, such as crime data, tends to be dependent on adjacent regions, a phenomenon known as spatial autocorrelation (also referred to as spatial dependence). The presence of spatial autocorrelation will produce biased and inconsistent estimates in regression [27]. Various spatial linear regression models have been developed to address the issue of spatial autocorrelation [28] and are widely adopted in crime studies. The validity of applying spatial regression is highly associated with spatial autocorrelation. If spatial data has spatial autocorrelation, it is preferable to employ spatial regression. The Global Moran's I statistic introduced by [29] and elaborately formulated by [30] is most often used for measuring spatial autocorrelation. The Global Moran's I value ranges from 1 (clustered) to -1 (dispersed). The value of 0 refers to no spatial autocorrelation indicating random distribution. The Global Moran's I offer a z-score and p -value representing whether the outputs are statistically significant.

Table 1 shows the results of spatial autocorrelation tests for the three crime rates. We applied the logarithmic transformation to the three crime rates (see the following Section 4.2 for the details) and a queen spatial matrix. The three crime rates had a positive spatial autocorrelation (clustered) with high statistical significance ($p < 0.001$). Hence, spatial linear regression models should be exploited to yield efficient and unbiased estimates by reflecting spatial autocorrelation.

Table 1. Results of Spatial Autocorrelation Tests for Crime Rates.

Crime Type	Global Moran's I	z-Score	p-Value
Theft rate (log)	0.2595	7.2851	0.0000
Violent crime rate (log)	0.2521	6.8141	0.0000
Sexual assault rate (log)	0.4111	11.2089	0.0000

Spatial linear regression models have been developed in a wide range of forms. Given the cross-sectional crime data, the current paper employs four basic spatial linear regression models [31]: a spatial lag model (SLM), a spatial Durbin model (SDM), a spatial error model (SEM), and a spatial autoregressive model (SAC). SLM is an extension of the traditional regression model, ordinary least squares (OLS), and its specific form is as follows:

$$y = \rho W y + \alpha \tau_n + X\beta + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \quad (1)$$

where y and X refer to the dependent and independent variable in the form of a column vector; W indicates the weight matrix (here queen matrix), and τ_n is a one-column vector; ε is the error term, and σ^2 is the variance of the error term; I_n is a $n \times n$ unit matrix. α , β , and ρ are coefficients to be estimated; Spatial lag effect can be captured by ρ , and thus its value and statistical significance are the most important to identify the impact of spatial autocorrelation.

SDM, also known as a special case of SLM, is developed to reflect both dependent and independent variables' spatial dependence simultaneously. SDM adds spatial lag effect to the independent variable as follows:

$$y = \rho W y + \alpha \tau_n + X\beta + WX\gamma + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \quad (2)$$

where γ is the coefficient of spatial lag on independent variables.

SEM is presented in Equation (3), where its error terms have spatial dependence:

$$y = X\beta + \mu, \mu = \theta W\mu + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \quad (3)$$

SAC assumes that spatial dependency exhibits in both the dependent variables y and the error term ε where spatial weight W_1 and W_2 may or may not be equal.

$$y = \alpha\tau_n + \rho W_1 y + X\beta + \mu, \mu = \theta W_2 \mu + \varepsilon, \varepsilon \sim N(0, \sigma^2 I_n) \quad (4)$$

Among various tools for spatial linear regression models, we used R with the “spdep” package [32].

4.2. Variables and Data

We summarize the variables and the data source used in the regression analysis in Table 2. Variables were selected by referring to previous studies and considering data availability. Early studies focused on the relationship between crime occurrence and space extensively controlled for intracity and intercity variations [33]. Environmental criminology focuses on the micro-level situational correlates of crime and identifies the physical environmental factors that could cause crime opportunities [34]. In this study, we selected variables considering both points of view. There are two reasons. First, robust intercity comparative crime analysis plays a crucial role in criminological concept formation [35]. In addition, identifying the factors that cause crime opportunities within a specific city is essential for crime prevention through environmental criminology. Therefore, it is necessary to consider intracity and intercity simultaneously. Second, it is crucial to actively consider factors that suppress or induce criminal opportunities in a microscopic spatial unit consistent with environmental criminology’s mainstream. Identifying the link between criminal chance and crime occurrence is essential for discussing environmental criminology’s applicability.

Table 2. Variable Definitions and Sources.

Variable	Description	Source
Dependent		
Theft rate (log)	Occurrence per 10,000 population	Korean National Police Agency
Violent crime rate (log)	Occurrence per 10,000 population	Korean National Police Agency
Sexual assault rate (log)	Occurrence per 10,000 population	Korean National Police Agency
Independent		
Vacant house	Proportion of vacant house to total house	Statistics Korea
Housing deterioration	House building year	Statistics Korea
Intersection density	Number of intersections per 10,000 population	Ministry of Land, Infrastructure, and Transport of South Korea
Mixed land use	Entropy index (residential, commercial, industrial, public, and amusement land use)	Ministry of Land, Infrastructure, and Transport of South Korea
Nighttime light (log)	Sum of nighttime light intensity	U.S. National Oceanic and Atmospheric Administration (NOAA)
Police officer	Population per a police officer	Korean National Police Agency
CCTV	Number of CCTVs per 10,000 population	Korean National Police Agency
Youth population (log)	Proportion of 15–29-year-old to total population	Statistics Korea
Single-person household	Proportion of one-person Household to total household	Statistics Korea
CDI	Combination both municipal financial independence rate and university graduate percent	Statistics Korea
Company (log)	Number of companies per 10,000 population	Statistics Korea

Note: CCTV and CDI indicate Closed-circuit television and Concentrated Disadvantage Index, respectively.

The dependent variables are theft, violent crime, and sexual assault rates. The distribution of all three dependent variables is skewed to the left, which does not meet the assumptions of parametric statistical tests. We utilize the logarithmic transformation to

conform to a more normal distribution [36]. The independent variables consist of the spatial environmental variables mainly used in the environmental criminology discussed above, and the police force variable and socio-economic variables known to be associated with crime at the neighborhood or region level. Each independent variable by three categories is as follows.

- Spatial environmental variables: vacant house, housing deterioration, intersection density, mixed land use, nighttime light
- Police force variables: police officer, closed-circuit television (CCTV)
- Socio-economic variables: youth population, single-person household, concentrated disadvantage index (CDI), company

As in other countries, most of the statistics in South Korea are based on administrative boundaries. However, the administrative boundaries and police districts in South Korea do not match, and thus constructing data for crime research involves many challenging issues. To address this, we extracted the boundaries of the police districts in ArcGIS 10.6.0 and manually matched administrative datasets with the police districts. Except for independent variables that can be easily understood through Table 2, we further explain the process of constructing variables in detail.

The intersection density was established through precise spatial analysis techniques. We first searched for road intersections with the spatial join tool and then found intersections where three or more overlap, defined as the road intersection for this analysis. The road intersections extracted from the study area were 1,696,095, and the number of intersections per 10,000 population was used as the final variable. To capture mixed land use, we accepted the entropy index, the most used index for representing mixed land use [37]. The entropy index is formulated as:

$$Entropy = \sum_j P_j \times \frac{\ln(P_j)}{\ln(J)}$$

where P_j denotes the proportion of the total land area of j land use category in a police district, and J indicates entire land uses in a police district. The higher value of entropy represents more mixed land use. For measuring mixed land use, we adopted the five specific land uses: residential, commercial, industrial, public, and amusement land use.

The U.S. National Oceanic and Atmospheric Administration (NOAA) provides nighttime lights calculated from weather satellite recordings as an annual time series. Of the three sources, we used “vcm-orm-ntl” (VIIRS Cloud Mask-Outlier Removed-Nighttime Lights). The sum of nighttime light intensity is extracted in police districts. CDI is an indicator of concentrated disadvantage at a local level. We adopted the two most dominant variables to reveal the local socio-economic level in South Korea: municipal financial independence rate and university graduate percentage. CDI was gained by normalizing these two variables and taking their averages using Z-score. Many environmental and socio-economic variables affecting crime often involve a multicollinearity problem in regression. The logarithmic transformation technique is applied for the three independent variables to mitigate multicollinearity: nighttime light, youth population, and company.

The independent variables in this study have been widely utilized in relevant studies. Thus, the claims and findings of related works can offer a baseline for comparing existing studies and results of South Korea. A tie between neighborhood environment and crime has long been explored and theorized in criminal-related research. According to the Broken Windows theory [20], the variance in crime is explained by the physical deterioration of a neighborhood. Many studies have found that this argument is highly persuasive [38–41]. We consider the vacant house and housing deterioration to see whether this claim can be supported in South Korea.

Intersection density stands for the connectivity of street networks, and higher intersection density indicates higher street connectivity [42]. Higher street connectivity may provide criminals with diverse escape routes and weaken access controls, leading to in-

creasing crimes [43–45]. On the contrary, constructing a pedestrian-friendly environment through higher street connectivity would effectively prevent crime by increasing natural surveillance [46,47].

For a similar reason to the intersection density, conflicting claims and evidence exist regarding the effects of mixed land use on crime. On the one hand, mixed land use creates a situation where residents and nonresidents converge in time and space [48], exposing them to more crime. Similarly, some studies posit that mixed land use, which degrades residents' social control, acts as a mechanism for increasing crime [49,50]. On the other hand, mixed land use exerts a salutary effect on crime [51–53]. The underlying substance of this argument is that mixed land use enhances mutual cohesion and facilitates social control, decreasing crime rates. One interesting point is that this assertion is supported by many spatial planners who believe that mixed land use complements the strict zoning system (e.g., a primary strategy of New Urbanism). Along with two conflicting arguments, there is also the assertion that the relationship between land use diversity and crime may vary by offense type [54,55].

A sufficient amount of lighting for activities during the night is one of the primary strategies of CPTED because it helps maintain visual acuity and surveillance in nighttime environments [56]. Articles have contended that higher nighttime intensity allows people to enhance surveillance opportunities, inviting fewer criminals [57,58]. Contrastively, lower nighttime night intensity may be combined with exposure to offenders, resulting in a higher probability of crime occurrences.

The relationship between the police force and crime rates has been one of the popular topics in criminology for a long time. The effect of police resources on decreasing crime rates has been controversial. Refs. [59,60] maintains that police resources can reduce crime by deterring potential offenders. However, there have been findings of a significant inverse and no relationship between the number of police officers and crime rates [61–63]. Although the crime-reduction effect of CCTV depends on the characteristics of the locations [64], a great deal of research has agreed with the proof that CCTV has a positive impact on the reduction of crime.

It is now a truism that socio-economic features represent one of the most influential factors associated with criminal behavior. Ref. [65] opines that the age-crime relationship is invariant, and crime rises rapidly in early adolescence, peaks in late adolescence, and rapidly decrease throughout the 20s. There are varied opinions on the realistic span of the age-crime curve, but many studies support the invariant age-crime parameters [66,67]. Because of less guardianship, single-person households are more vulnerable to crime [68]. Since the Chicago School, social or neighborhood disadvantages have played a role in explaining criminal behavior [69]. As noted earlier, an enormous body of work on environmental criminology has paid much attention to neighborhood disadvantages as a critical factor in increasing crimes. We use CDI to examine whether this claim is appropriate in a South Korean context.

The association between the number of companies and crime can be explained from two perspectives. First, as discussed above, according to the social control perspective, more companies mean more floating populations, leading to impacts on crime, whether salutary (advantage surveillance) or deleterious (disadvantage social control). The other is the regional economic point of view. The higher the number of companies, the lower the probability of crime, since regions with poor finance are prone to crime [70,71].

5. Results

5.1. Regression Model Selection

Before explaining the determinants of crime rates, we choose the most appropriate spatial regression model by crime type (see Table 3). Of all four spatial regression models, we select one model that has the best statistical power. Two steps determine the model selection. As spatial regression models are applied, the first step should be statistically significant for ρ and γ , meaning spatial autocorrelation (at least $p < 0.05$). In the second

step, we select the appropriate model based on the Akaike information criterion (AIC) value. The model with the smallest AIC is preferred. To take the theft rate as an example, except for SAC, all meet the first step because ρ and γ are statistically significant. Since the AIC value of SEM is the smallest among the three models, the best model for the theft rate is SEM. Using this same approach, the best spatial regression models for violent crime rate and sexual assault rate are SEM and SAC, respectively. In the following section, we will explain the regression results for the three types of crimes based on the selected model.

Table 3. Comparison of Spatial Regression Models and Model Selection.

Crime Type	Statistics	SLM	SDM	SEM	SAC
Theft rate	AIC	130.18	134.64	122.94	122.87
	ρ	0.1878 (**)	0.3123 (***)	-	-0.2119
	γ	-	-	0.3380 (***)	0.5004
	Model Selection	-	-	○	-
Violent crime rate	AIC	22.06	14.98	8.37	11.27
	ρ	0.1716 (*)	0.3601 (***)	-	-0.2053
	γ	-	-	0.4253 (***)	0.5542 (***)
	Model Selection	-	-	○	-
Sexual assault rate	AIC	38.44	28.09	34.56	33.67
	ρ	0.0854	0.1047	-	-0.2363 (*)
	γ	-	-	0.2701(*)	0.5140 (***)
	Model Selection	-	-	-	○

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

5.2. Regression Results

Table 4 displays the descriptive statistics for each variable adopted in the analyses. The variance inflation factor (VIF) values are below 6.6 in all the models, indicating no multicollinearity problems.

Table 4. Descriptive Statistics of Variables ($n = 216$).

Variable	Mean	SD	Minimum	Maximum
Theft rate	12.70	0.43	11.41	14.51
Violent crime rate	13.16	0.37	12.04	14.46
Sexual assault rate	10.69	0.49	9.38	12.52
Vacant house	8.66	4.87	0.51	20.79
House deterioration	30.43	9.60	11.72	49.61
Intersection density	49.47	82.79	0.81	493.19
Mixed land use	0.48	0.40	0.05	1.39
Nighttime light	8.66	0.77	6.58	10.62
Police officer	489.25	183.13	125.37	1021.10
CCTV	48.25	28.78	10.41	206.70
Youth population	2.84	0.18	2.38	3.19
Single-person household	30.31	5.32	17.70	45.10
CDI	0.00	0.85	-1.11	3.77
Company	6.69	0.29	6.14	8.57

Table 5 summarizes the regression result of the theft crime rate derived from SEM. The vacant house had a negative impact on the theft crime rate, and house deterioration had no relationship with the theft crime rate. In light of these results, neighborhood deterioration was not directly connected to South Korea's theft crime. Unlike the intersection density, more mixed land use increased the theft crime rate ($p < 0.01$). This finding is in line with previous arguments that more mixed land use can reduce social control while increasing crime exposure. The higher the nighttime light intensity, the higher the likelihood of theft crime ($p < 0.001$). In general, brighter nighttime light can prevent crime by increasing

surveillance, but this notion was not valid for the theft crime in South Korea. Instead, bright nighttime light can increase the amount of nighttime activity, augmenting the chance of being exposed to crime. Based on the lower theft crime rate, the larger the population in charge of police officers, the distribution of police force in South Korea is relatively efficient for repressing theft crime. Unlike police deployments, CCTV was not associated with curbing the theft crime rate. Except for the youth population, socio-economic variables were closely related to the theft crime rate. The theft crime rate increased with more single-person households ($p < 0.001$), higher CDI ($p < 0.001$), and a more significant number of companies ($p < 0.05$). Less guardianship, neighborhood disadvantages, and more floating populations can be directly associated with the theft crime rate.

Table 5. Regression Result of Theft Crime Rate (SEM).

Variable	Estimate	Std. Error	Z Value
Intercept	8.6148	1.0121	8.5116 (***)
Vacant house	−0.0205	0.0083	−2.4560 (*)
House deterioration	−0.0689	0.0466	−1.4795
Intersection density	0.0648	0.0524	1.2375
Mixed land use	0.1736	0.0645	2.6924 (**)
Nighttime light	0.1954	0.0533	3.6657 (***)
Police officer	−0.0011	0.0027	−4.0671 (***)
CCTV	0.0045	0.0090	0.5034
Youth population	−0.1806	0.2407	−0.7504
Single-person household	0.0182	0.0067	2.7399 (***)
CDI	0.1286	0.0499	2.5782 (***)
Company	0.2098	0.1014	2.0694 (*)
γ	0.3380 (***)	−	−

AIC: 122.94; Log likelihood: −47.46; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6 represents the determinants of violent crime rate based on SEM. Even if house deterioration negatively affected the violent crime rate, a more reasonable interpretation is that neighborhood deterioration was not closely correlated with the violent crime rate in South Korea. The impact of intersection density, mixed land use, and nighttime light on the violent crime rate was consistent with the results of the theft crime above. That is, the effect of intersection density was not confirmed, and more mixed land use ($p < 0.001$) and brighter nighttime light ($p < 0.001$) increased violent crime occurrence. The distribution of police officers effectively combats violent crimes ($p < 0.05$), but there was no link between CCTV and violent crimes. Districts with a more youth population were more vulnerable to violent crime ($p < 0.01$), indicating a substantial age effect on violent crime in South Korea. In areas with high CDI, the violent crime rates were lower ($p < 0.001$). Conversely, it can be said that violent crimes tend to occur in more prosperous places in South Korea. Many companies also acted as inviting more violent crimes ($p < 0.001$).

Table 7 shows SAC's regression result of the sexual assault crime rate. The sexual assault crime rate was not closely related to the physical conditions of the neighborhood. Intersection density was the only correlation with the sexual assault crime rate of the three crime types. The greater the intersection density, the higher the odds of sexual assault crime ($p < 0.05$), demonstrating that increased street connectivity is favorable for the criminal behavior of sexual assault in South Korea. Mixed land use and nighttime light are critical in raising the probability of sexual assault crime ($p < 0.001$). The police force, in terms of both the geographical distribution of police officers and CCTV, was not connected to the sexual assault crime rate. Among socio-economic variables, single-person households and a number of companies were associated with a sexual assault crime. In districts where many single-person households live, the sexual assault crime rate is more likely to be higher ($p < 0.001$). Given that women are the most victims of sexual assault crime in South Korea, areas with more women living alone were more susceptible to being exposed to sexual

assault crime. As with the other two types of crime, areas with larger companies were more likely to be exposed to sexual assault crime ($p < 0.001$).

Table 6. Regression Result of Violent Crime Rate (SEM).

Variable	Estimate	Std. Error	Z Value
Intercept	7.7885	0.7812	9.9701 (***)
Vacant house	−0.0134	0.0640	−0.2096
House deterioration	−0.0738	0.0364	−2.0247 (*)
Intersection density	0.0605	0.0405	1.4937
Mixed land use	0.1768	0.0505	3.4977 (***)
Nighttime light	0.1402	0.0409	3.4278 (***)
Police officer	−0.0042	0.0021	−2.0407 (*)
CCTV	0.0050	0.0069	0.7333
Youth population	0.4389	0.1850	2.3731 (**)
Single-person household	0.0052	0.0051	1.0241
CDI	−0.1092	0.0397	−2.7490 (***)
Company	0.4982	0.0772	6.4552 (***)
γ	0.4253 (***)	−	−

AIC: 8.37; Log likelihood: 9.81; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 7. Regression Result of Sexual Assault Crime Rate (SAC).

Variable	Estimate	Std. Error	Z Value
Intercept	10.8992	1.9288	5.6508 (***)
Vacant house	−0.0744	0.0674	−1.1044
House deterioration	−0.0128	0.0389	−0.3282
Intersection density	0.0109	0.0043	2.5294 (**)
Mixed land use	0.1936	0.0560	3.4590 (***)
Nighttime light	0.1447	0.0429	3.3737 (***)
Police officer	−0.0034	0.0022	−1.5628
CCTV	−0.0070	0.0072	−0.9730
Youth population	0.1541	0.1950	0.7901
Single-person household	0.0142	0.0053	2.6905 (***)
CDI	0.0581	0.0443	1.3121
Company	0.4703	0.0858	5.4837 (***)
ρ	−0.2363 (*)	−	−
γ	0.5140 (***)	−	−

AIC: 33.67; Log likelihood: −1.83; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

We summarize the regression results as follows. The most prominent finding is that the regression results in the three crimes are slightly different. A generalized strategy applicable to all crimes is required [6] for more effective anti-criminal operations, but the current analyses show that this approach is challenging in reality. Nevertheless, the same influential variables in all three crime types can be adopted as a generalized strategy for preventing major crimes in South Korea.

The broken windows effect was negligible for significant crimes in South Korea. The result is consistent with the basic idea suggested in [50] that increased disorder is not a causal factor of serious crime. Considering the environmental characteristics of physical activity in South Korea, such a result can be convincing. Since 1995, when the local autonomy system was regularized, local governments have significantly improved their physical properties. As a result, the influence of regional disorders on the incidence of crimes was marginal. Another interpretation is possible. In South Korea, neighborhood deterioration in rural areas is more severe than in urban areas, and due to the low crime rate in rural areas, the effects of the broken window did not work.

In the three crime types, mixed land use affected rising crime rates, which is a line with some previous studies that mixed land use increases the likelihood of crime incidences [48,49]. South Korea has run a zoning system to control land use, which is equivalent to the U.S., but the level of mixed land use is very high compared to the countries of the world. Although new planning ideas such as New Urbanism encourage human activities through mixed land use, mixed land use in South Korea has been found to cause crimes. Thus, proper intervention is needed from a crime-prevention standpoint.

Unlike a series of relevant works, brighter nighttime light has not effectively decreased crimes in South Korea. The result can be understood through South Korea's unique nightlife. South Korea is one of the countries with the most developed nightlife. Even after midnight, it is common for many people to enjoy the nightlife in various regions. Most restaurants and convenience facilities are open until late dawn, welcoming people who want to entertain nightlife. The nightlife is more intense in areas with brighter nighttime light. Thus, those engaged in nightlife are more subject to crime. Policies that effectively control and manage nightlife may be more practical than offering brighter nighttime light.

In South Korea, CCTV was not found to play a role in deterring crimes. As [64] noted, the crime prevention effect of CCTV is directly related to its location, so efforts to increase the efficiency of CCTV location will emerge as one of the essential crime prevention strategies in South Korea. This study proved why location-oriented approaches in terms of CCTV should be accompanied by not just the number of CCTVs in districts.

Lastly, socio-economic characteristics were closely connected with crime rates in South Korea. In all three crimes of the study, a number of companies allured offenders to commit crimes. In a violent crime, the impact of youth populations was identified. A district with more single-person households tends to have higher theft and sexual assault crime rates. CDI increased theft crime and decreased sexual assault crime and vice versa. The Chicago School's argument that neighborhood disadvantages cause more offenses is still valid in South Korea. Thus, efforts to improve neighborhood environments will be regarded as an important policy for crime-free areas.

6. Conclusions

Is environmental criminology applicable to our places? Yes, it is. The theft rate, violent crime rate, and sexual assault rate confirm the reliability of environmental criminology. Although this study has examined the likelihood of applying environmental criminology, further research and discussions are followed for concrete plans. From effective spatial planning to policy applications, many research fields have not yet been validated through the lens of environmental criminology. With the public's interest, follow-up studies should dive deeper into finding practical spatial planning and policy strategies to suppress crimes.

Like other extensive previous studies, this study confirmed the possibility of environmental criminology. However, it does not mean that the significant factors in environmental criminology affect crime similarly. Among the results of this study, the broken windows effect, mixed land use, and several socio-economic features were found to be effective in crime prevention. Nevertheless, other variables showed different results by crime type. So, how should we find a general strategy for applying environmental criminology? In conclusion, finding the answer in a specific space is the only way. An effort to identify the relationship between environmental criminology and crime occurrences is crucial by focusing on the heterogeneous characteristics of space. The influence of environmental criminology can be large or small depending on the different features of the space. The key is respecting environmental criminology's rationale and exploring more meaningful strategies. The most important task is to track the cause of crime in a specific space for an extended time and to find a general application strategy of environmental criminology. Using big data ([72,73]) and new techniques, such as machine learning [74], should be actively accepted to enhance the reliability of environmental criminology.

Since the spatial autocorrelation of crime rates is confirmed in South Korea, it will be necessary to actively consider spatial autocorrelation in subsequent studies. Under

the premise of spatial autocorrelation in crime data, follow-up works should produce more general outputs by actively applying spatial panel regression models rather than cross-sectional analysis. Additionally, microscopic studies will be preferred for mitigating structural limitations of aggregated data (e.g., ecological fallacy and modifiable areal unit problem). Further, environmental criminology should be actively used for crime prediction. As with this study, studies analyzing environmental criminology's effects and possibilities in various countries or regions should continue to extend their valid generalization and utilization.

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