Master's Thesis of Economics

The Effects of Spatial Characteristics on Violent Crime Incidence and Violent Crime Hot Spots in Korea

– Applications of Linear and Discrete Spatial Econometrics Models –

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Graduate School of Agricultural Economics and Rural Development
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Abstract

The primary purpose of this study is to investigate the causal inference between violent crime and spatial characteristics of local area utilizing spatial linear models and spatial discrete choice models and to propose alternative public policies for desirable urban environments in South Korea. The spatial variables adopted in this study are the proportion of hotel and restaurant businesses in an area, and road accessibility. These two variables are important factors that reflect the industrial structure and population influx. This dissertation is composed of two essays.

In the first essay, the impacts of the demographic, socio-economic, and spatial factors on violent crime are analyzed utilizing sever spatial linear models. The results reveal that the increase in the number of hotel and restaurant businesses is positively associated with the incidence of crime. In addition, enhancement of the road accessibility has a positive effect on crime.

The second essay analyzes the effects of the spatial variables on violent crime hot spot using spatial discrete choice models. The results show that the impact of the spatial variables that determine violent crime hot spots proves to be highly effective. The proportion of the hotel and restaurant establishments shows positive effects on determining violent crime hot spots. Furthermore, the higher the road accessibility of an area, the higher was the probability of becoming a violent crime hot spot.

Regional characteristics clearly affect the level of crime incidence. Based on the findings, this thesis suggests some implications to urban planners and policymakers. Further studies on the relationship between crime and urban planning policies are necessary for crime prevention and safer urban communities. In particular, interdisciplinary research between criminology and urban planning is essential to prevent crime in urban areas.

Keyword : Crime Incidence, Crime Hot Spot, Spatial Linear Models, Spatial Discrete Models, Accessibility, Urban Planning

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Chapter 1. Introduction

1.1. Objective of the Study

Empirical application to explain criminogenic events and environments from Western experiences is abundant. The applications have delivered social and economic factors such as race, age, gender, income inequality, education, poverty, and social exclusion as major independent variables to determine crime incidence. Although most criminal studies still focus on motivation of offenders and avoidance of victimization in the micro perspective, there have been some theoretical developments handing priority to space as a direct factor that influences crime incidence. This approach may be more insightful for planners and policy makers if major concern is to understand crime rather than criminality as public policy concerns more on crime prevention instead of criminal control. The primary purpose of this study is to investigate the causal inference between violent crime and spatial characteristics of local area utilizing spatial discrete choice models and to propose alternative public policies for desirable urban environments in South Korea.

Crime incidence is not uniformly distributed over space, an argument that can date back over a century. However, it is Chicago ecological school represented by Shaw and McKay (1942), to initiate identifying the relationship between spatial factors and crime incidence in a robust academic insight. The prime question in this perspective is what spatial conditions determine regional variations in crime rates. The relationship between spatial factors and crime has been investigated in diverse geographical contexts. These studies have the common assumption that diverse spatial factors have direct effects on crime incidence irrespective of national and/or cultural contexts.

Recognition of space to crime is derivative. Increasing concerns

on spatial characteristics of crime causality are widespread in western societies. However, much less known are empirical evidences of crime incidence from Asian countries including South Korea. Do these explanations hold for other countries that have quite heterogeneous historical and cultural backgrounds? In a rare attempt at comparative analysis, Clinard (1978) showed that there exist pronounced differences in causes and consequence of crime incidence between the US and Switzerland. Hooghe *et al.* (2011) also argued that a construct to explain crime incidence that is true for one country cannot be applied to another country.

Studying built environment and spatial characteristics on crime is an important part of the Crime Prevention Through Environmental Design (CPTED) (Schneider and Kitchen, 2002). Crime is a spatial phenomenon and therefore mirrors spatial characteristics of a certain region. It is not easy, however, to detect the effects of regional variables on crime. Since crime is heavily influenced by the structure of built environment (Paulsen, 2011), this study will try to investigate how spatial characteristics affect crime incidence and crime hot spot. In addition, this thesis tries to find out the causal inference between crime and spatial features utilizing diverse spatial econometrics models, and proposes alternative policies for desirable public service to ensure public safety.

The remaining parts of this thesis is as follows. Chapter 1 explains the diverse perspectives in crime theories, crime experiences in Korea, research hypotheses and structure of this thesis. Next two chapters is composed of the two empirical applications of crime: Chapter 2 presents an empirical application of crime incidence with the application of linear spatial econometrics models, and Chapter 3 applies spatial discrete econometrics models to investigate the effects of spatial characteristics on crime hot spots. The final chapter (Chapter 4) summarizes the findings from the two empirical studies along with presenting limitations and future directions of this thesis.

1.2. Background

1.2.1 Theories on Crime

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 (1942) 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.

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. Routine activity 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.

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 become 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. 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 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 routine activity theory 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 routine activity 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 routine activity 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, routine activity theory 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 routine activity theory conclude that measures of expenditure to crime (e.g., nighttime leisure activity, non-household 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 in areas, 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 (1973) 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 and Braintingham (1981) explains that crime is composed of laws, criminals, targets, and places and their mutual reactions. CPTED (Crime Prevention Through Environmental Design) and Defensible Space are the best theoretical insights in this perspective. Following this argument, Brown (1982) studies on spatial distribution patterns of crime with spatial autocorrelation effects analysis. Applications of diverse GIS analyses and other mapping analyses on crime are the typical line of reasoning in this perspective to examine the effects of various regional characteristics on crime.

Spatial efficiency and equity may seem analogous, but there are distinctive differences between the two; the former focuses on the facilities themselves, while the latter focuses more on the consumers. Spatial equity essentially implies an equitable distribution of urban facilities among population groups such that no particular group is at

an advantage or disadvantage simply because of their spatial location. Spatial efficiency aims to achieve maximum efficiency with limited resources, while spatial equity aims to rectify spatial inequality, a social phenomenon where certain attributes of population groups are aroused in a spatially uneven manner (Kim and Sultana, 2015).

In general, the location of public facilities aims to maximize the interactions among regions with less cost and effort, as classical location models identify the location with least transport expenses under the presumption that transport expenses are proportional to the distance. However, in reality, as the assumption is affected by diverse factors—such as transportation, road conditions, and traffic—various factors that are relevant to distance in location theories are understood as an inclusive concept. Accessibility, which refers to the degree of availability of something to as many people as possible, is widely adopted as an important factor in determining the location of a public facility, which has characteristics of a pure public good—"non-rivalry" and "non-excludablity." In the determination of the optimal location of public facilities, economic efficiency should be considered, as these facilities are public goods① rather than economic goods.

These characteristics can best be represented by spatial built environment of social overhead capital, that is transportation accessibility condition. In this regard, accessibility is widely used as a representative factor of economic efficiency. Over the years, a steadily increasing number of studies have evaluated the location of public facilities based on accessibility (Talen and Anselin, 1998; Talen, 2003; Tsou *et al.*, 2005). Accessibility is classified into revealed accessibility and potential accessibility. The former relates to the use of the facility and the latter is relevant to the opportunities associated with the facility (Phillips, 1990). When analyzing the

① This implies that no individual can be excluded from the use of such a good and that if one (or more) individual(s) does utilize the good, it does not reduce its availability to other individuals.

revealed accessibility of a certain facility, revealed accessibility only considers the actual users of the facility, while potential accessibility does not restrict the scope of users. For accessibility analyses in practice, potential accessibility is generally preferred to revealed accessibility due to the data availability reasons. Depending on the analytic perspectives, accessibility is also classified into spatial factors and non-spatial factors (Donabedian, 1973).

1.2.2. Crime in Korea

Seoul, the capital city of Korea, has a special meaning for most people in Korea. It is true that Korea relies heavily on the Seoul in almost every social and economic aspect. Occupying about 12% of the country's total area in 2020, the Seoul Metropolitan Area(SMA) held 50.24% of the total population. In addition to the share of the population, most widely cited statistics for the Seoul Metropolitan Area dominance over the rest of the country are 51.92% of the nation's GRDP (gross regional domestic product, 40.52% of manufacturing firms, 62.48% of total R&D workers, 84 of the headquarters of 100 major large enterprises, 70% of deposits, 65.36% of total loan amount, 77.8% of total public administrative offices and 34.22% of universities in 2019 (KOSIS).

Its dominance is even more pronounced in terms of fiscal resources, accounting for 66.81% of personal income tax receipts and 61.36% of corporate income tax receipts in 2019 (KOSIS). 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 Metropolitan Area 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 crueler, 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 the 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.

<Table 1-1> illustrates the change of crime incidence in Korea. In Korea, the total number of crimes in 2005 was 1,893,896 and increased to 2,020,731 in 2015. The arrest rate decreased about 4.6 percent point during ten years. The number of criminal offenses, which denote the crimes obeying criminal law, also increased from 2005 to 2015 and the arrest rate diminished during the same period. On the other hand, the number of violent crime [②] incidences decreased. It diminished more than 15,000. Moreover, the arrest rate rose about three percent point. The notable part is that the number of heinous crime which is composed of murder, burglar, arson, and sexual violence increased nearly double in ten years. This is quite serious in that heinous crime poses a direct threat to human life.

[②] Violent crime consists of murder, burglar, arson, sexual violence, assault, wounding, threat, menace, kidnapping, arrest and imprisonment and other violently illegal acts.

Table 1-1. Crime Incidence in Korea, 2005-2015

		2005	2010	2015
Total Crime				
	Incidence	1,893,896	1,917,300	2,020,731
	Arrest	1,624,522	1,620,942	1,638,549
	Arrest Rate (%)	85.78	84.54	81.09
Criminal Offense				
	Incidence	825,840	939,171	1,047,761
	Arrest	634,244	710,146	784,441
	Arrest Rate (%)	76.80	75.61	74.87
Violent Crime				
	Incidence	299,615	266,490	283,846
	Arrest	273,713	244,501	268,195
	Arrest Rate (%)	91.35	91.75	94.49
Heinous Crime				
	Incidence	19,941	27,482	35,139
	Arrest	17,059	24,304	33,846
	Arrest Rate (%)	85.55	88.44	96.32

1.3. Research Hypotheses

There exist some crime studies about the crime incidence in Korea to be published in international society (Choi and Chin, 1998; Choi, 2003; Yoon and Joo, 2005). Those studies have relied heavily on sociological perspective and the spatial considerations on crime were hardly found due largely to inaccessibility to basic crime data at a regional level. In limited empirical studies, Choi (2003) studied 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.

Choi and Jin (1999) tried to examine the relation between regional characteristics and crime rate with longitudinal and cross-sectional analysis. They noted 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 that of rural and metropolitan areas because of higher population influx. Applying time series data, Yoon and Joo (2005) examined roles of economic conditions, organizational constraints of police and political climate in explaining crime rates in Korea. They found that economic and political structures are the important factors to deter crime incidence.

However, those studies are limited in that they assumed the covariates of crime are invariant over space. This assumption may be inappropriate since many prior studies on crime in diverse contexts have witnessed evidence of spatial dependencies (Andresen, 2006; Baller *et al.*, 2001; Brownning *et al.*, 2011; Byeon *et al.,* 2020; Cahill & Mulligan, 2007; Hipp, 2007; Kim and Lee, 2011; Kim and Lee, 2013; Lauridsen *et al.,* 2013; Lee and Choi, 2019; Lee, 2018; Leiva *et al.,* 2020; Morenoff *et al.*, 2001; Piatkowska *et al.,* 2020). In other words, little attention has been given to the effects of spatial dependencies and heterogeneities on crime incidence in Korea.

Another deficit in Korean literatures on crime is ignorance of the possibility of contextual disparity in crime studies. Increasing concerns on spatial characteristics of crime causality are widespread in western societies (Eck and Weisburd, 1995). However, much less known are empirical evidences of crime incidence from Asian countries including South Korea. Do these explanations hold for other countries that have quite heterogeneous historical and cultural backgrounds? Furthermore, scant attention has been given to crime on spatial implication.

Based on the brief overview of the crime literature and crime occurrence in Korea, rather straightforward two hypotheses are constructed to be tested in this dissertation.

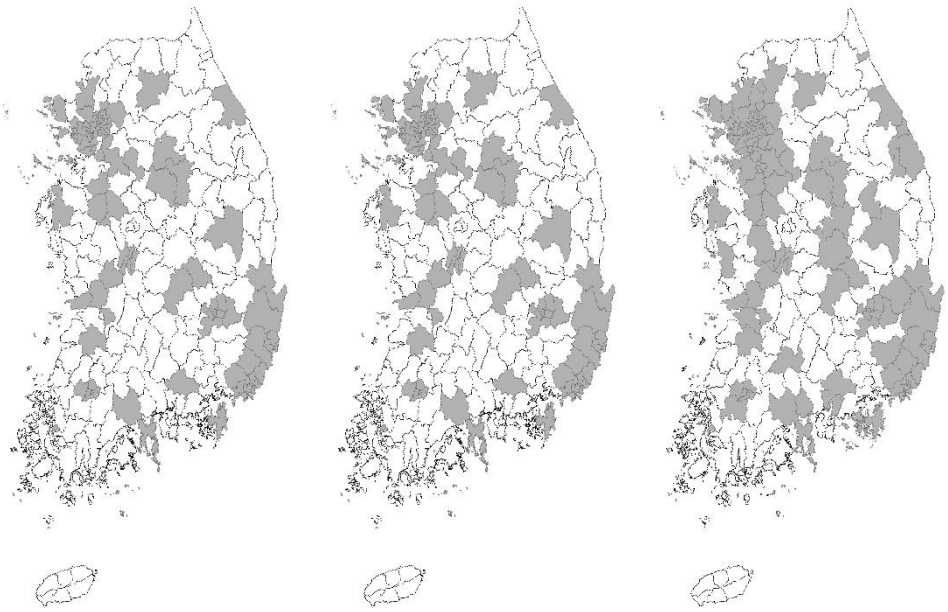
– H1. The effect of spatial variables will be significantly associated with high level of violent crime. The effect should be statistically significant even when controlling for other demographic and socio–economic characteristics of areas.

– H2. Spatial characteristics of areas will be important factors to identify violent crime hot spot. The distribution of the hot spot will be unevenly disposed.

By including spatial characteristics and incorporating spatial econometrics models, this study takes a comprehensive approach to the study of violent crime incidence and violent crime hot spot that recognize the importance of space and built environment in crime studies. This study argues that neglecting these points neither guarantee high quality studies on crime nor catch detailed phenomena of crime incidence.

1.4. Structure of the Study

<Figure 1-1> depicts the subject regions of the present study. The two panels on the left side are data from the Supreme Prosecutors' Office of the Republic of the Korea (SPO) and there were 116 areas in 2005 and 2010. The data in the right panel came from the SPO and the National Police Agency of Korea (KNPA). The number of subject regions was 145 in 2015.



2005 2010 2015

Figure 1-1. The Research Subject Regions, 2005-2015

Following the introduction in Chapter 1, Chapter 2 investigates the determinants of violent crime incidence paying particular attention to spatial effects on violent crime incidence. Since violent crime incidence is in general closely related to the spatial characteristics of a city, diverse spatial econometrics models will be applied (Spatial Autoregressive Regression, Spatial Error Model, Spatial Autoregressive Confused Model, Spatial Durbin Model, etc.) to incorporate the regional characteristics into the statistical models. With diverse socio-economic variables of areas, the spatial variables that will be adopted in this chapter are the proportion of the hotel and restaurant businesses and the road accessibility.

Chapter 3 will examine the determinants of the violent crime hot spot to investigate the effect of spatial variables on crime hot spot. Since violent crime hot spots are closely related to the spatial characteristics of a city, two spatial econometrics models (Spatial Autoregressive Probit Model, Spatial Error Pobit Model) will be

applied to incorporate diverse regional characteristics into the statistical model. LISA will be utilized to determine the violent crime hot spot and will be mapped to examine the geographical clusters of each independent variable on identifying the violent crime hot spot.

The final chapter summarizes major findings from the two empirical applications and proposes planning and policy implications, limitations and directions of future studies. With the provision of the compact research summaries, the purpose of the chapter is to encourage planners and policy makers to take more seriously the relationship between crime prevention measures and built environment to construct some feasible public policies.

Chapter 2. Determinants on Violent Crime Incidence: Application of Spatial Linear Models

2.1. Introduction

Theoretical arguments to explain criminogenic events and environments from western experiences include social and economic factors, such as race, age, gender, income inequality, education, poverty, and social exclusion as major covariates to determine the incidence of crime (Buonanno, 2006). Some recent studies have proposed geographical and political factors, including (mixed) land use, residential concentration, political structure, and presence of deterrent public activities, such as the police distribution (Browning *et al.* 2010; Kim and Lee, 2013; Yoon and Joo, 2005).

While many criminal studies have focused on the motivation of offenders and avoidance of victimization in the microperspective, there have been a number of theoretical developments emphasizing space as a direct factor that influences the incidence of crime. Empirical applications of this perspective can be found in Cahill and Mulligan (2007), and Stucky and Ottensmann (2009). This approach may be more insightful for policymakers if the major concern is to understand crime rather than criminality, as public policy is concerned with preventing crime rather than controlling the offender.

rime is not uniformly distributed over space, which is an argument that dates back over a century (Eck and Weisburd, 1995). The Chicago Ecological School, represented by Shaw and McKay (1942), first identified the relationship between spatial factors and the incidence of crime (Herbert, 1982). The prime question from this perspective is: What spatial conditions determine regional variations in crime rates? The relationship between spatial factors and crime has been investigated in a variety of geographical contexts (Blau and Blau, 1982; Brantingham and Brantingham, 1995; Goudriaan *et al.*, 2006; Hooghe *et al.*, 2011). These studies assumed that a variety of

spatial factors have direct effects on the incidence of crime regardless of the national and/or cultural context.

Increasing concerns regarding spatial characteristics for the causality of crime are widespread in western societies (Eck and Weisburd, 1995). However, much less empirical criminal evidence is available from Asian countries, including Korea. Do these explanations hold for other countries that have heterogeneous historical and cultural backgrounds? This question is particularly relevant regarding the empirical evidence from Clinard (1978). In a rare attempt at comparative analysis, Clinard (1978) showed pronounced differences in the crime rates between the US and Switzerland that cannot be explained by general crime theory. Hooghe *et al*. (2011) argued that a construct to explain the incidence of crime that is true for one country cannot be applied to another country.

Spatial impacts on the incidence of crime can be controlled by spatial planning schema operated at a variety of governmental levels. Although spatial planning practice does not consider all spatial effects, key factors closely related to crime can be managed through spatial planning practices. Therefore, it is important to investigate the relationship between major spatial planning factors and the incidence of crime.

The present study was aimed at analyzing empirically the prevalence of violent crime in Korea to understand the relationship between spatial factors and the incidence of crime. Various spatial econometrics models were applied to identify factors between the incidence of violent crime and spatial planning factors. The spatial variables adopted in this study are: the proportion of hotel and restaurant businesses in an area, and road accessibility. These two variables are important factors that reflect the industrial structure and population influx. Based on the findings from these analyses, the present study suggests some implications for spatial planning to prevent crime.

The present study pays particular attention to the recent

development of spatial econometrics modeling in the field of criminology because covariates to determine the incidence of crime perform differently in different spaces (Brownning *et al.*, 2010; Cahill and Mulligan, 2007; Cheong, 2014; Hipp, 2007; Hooghe *et al.*, 2011; Kim and Lee, 2013; Lee and Cho, 2006; Park *et al.,* 2018). These studies show that ignorance of the possibility of spatial differences between covariates and the incidence of crime can result in violation of the basic assumption (i.e., independence of observation) of many standard statistical models, as spatial dependence and spatial autocorrelation are widespread in most spatial data (Anselin, 1988). Cahill and Mulligan (2007) argued that applying spatial data in ecological studies of crime is useful even when local processes are not theoretically identified. Following these insights, the potential for the impact of spatial heterogeneity on the incidence of crime in Korea was considered in models.

2.2. Background

While few authors in the fields of urban and regional planning argue that crime is a serious urban and regional issue, increasing concerns are now focused on the overlapping research interests between urban planning and crime prevention (Paulsen, 2011; Schneider and Kitchen, 2002). The major field of urban and regional planning is interconnected with the academic domain of criminology in that urban and regional planning are involved with the design of diverse spatial structures, such as spatial connectivity, mixed land use, zoning, and transit-oriented development, and criminology is concerned with the impacts of those environments on the incidence of crime. These duplicated traits of the two fields are particularly relevant in the association of the provision of public services and crime prevention.

Modern cities are becoming larger, over-populated, and centralized, while the demand for sophisticated urban services is growing due to the improved standard of living in Korea. In this

regard, research on the provision of public services has grown, most of which concerns the centralized or weighted supply of resources on a regional basis. The most widely adopted criteria for evaluating public service facilities are spatial efficiency and equity (Bach, 1980).

As the increasing crime trend is a major factor impeding social development, attention has been paid to crime in the social sciences, including criminology. Most of the attention has thus far been placed on detecting and apprehending the actors committing the crimes, while more efforts are currently being made to understand the macroscopic factors that influence crime, such as social, economic, and institutional factors.

Various macroscopic sociological explanations of crime explain criminal factors. Social disorganization theory is one of the most widely recognized sociological theories. Suggested by Shaw and McKay (1942), this theory assumes that crime is closely related to social disorganization, a phenomenon associated with losing collective voluntary control through the lack of social solidarity and integrity. Factors including poverty, residential mobility, diversity of races and ethnic groups, population density, family disorganization, and single-parent families are commonly adopted to measure the extent of collective control of a community. Many studies have focused on these factors to investigate their relationship with crime. It is commonly accepted and reported that social disorganization is closely related to the incidence of crime (Barnet and Mencken, 2002; Bruinsma *et al.,* 2013; Lee and Choi, 2019; Petee and Kowalski, 1993; Petee *et al*., 1994; Sampson and Groves, 1989; Warner and Pierce, 1993; Witt, *et al*., 1999).

Another representative theory that explains crime determinants from a sociological perspective is routine activity theory. Suggested by Cohen and Felson (1979), this theory is focused on local environment and circumstantial conditions. According to this theory, crime occurs when criminal offenders and targets exist, while the circumstantial conditions are a lack of control that deters crime (Hollis-Peel *et al.* 2011; Kim *et al.,* 2014; Louderback and Roy, 2018;

Miller 2013; Paulsen and Robinson, 2004; Roncek and Maier 1991; Smith *et al.,* 2000). Crime never occurs if any of the three conditions is not satisfied. This theory has everything to do with spatial planning factors, as spatial planning immediately aggravates or improves the circumstantial conditions.

Economic approaches to crime assume that there is a close relationship between crime and an opportunity for economic activity (Corman and Mocan, 2005; Mocan and Rees, 2005). In other words, based on the rational expectation hypothesis, these approaches insist that crime occurs when more benefits are expected than costs (Becker, 1968). Economic approaches can be largely divided into microscopic and macroscopic approaches. While microscopic approaches focus on the individual criminal's behavior, macroscopic approaches stress the importance of the economic condition of the community or region, such as unemployment and income disparities. It is widely reported that the less economically activated a region or community is, the more crime occurs, and this theory has been supported by many empirical applications in diverse contexts (Andresen, 2006; Byeon *et al.,* 2020; Ceccato *et al.*, 2002; Chun and Park, 2008; Han *et al.,* 2013; Hooghe *et al.*, 2011; Ko, 2016; Lauridsen *et al.,* 2013; Lee and Cho, 2006; Sampson and John, 1987).

The defensible space theory is a pioneering perspective pursuing crime prevention through the lens of spatial planning as suggested by Newman (1973). This theory approaches crime prevention strategies from an architectural standpoint, insisting that extensive control of territoriality, natural surveillance, image, and milieu prevents and decreases crime. More recently, crime prevention through environmental design (CPTED) has emerged as an important strategy for crime prevention planning. CPTED is a strategic approach to deter crime and reduce the fear of crime through appropriate design and effective use of the architectural environment. Interest in CPTED has increased in Korea as well as in western countries. Several studies have focused on the effects of spatial planning factors on the incidence of crime by incorporating

these perspectives. The spatial factors described above have an immediate impact on crime. The spatial factors that have earned most of the research interest are spatial connectivity (Cozens and Love, 2009; Hiller and Shu, 2000; Johnston and Bowers, 2010), mixed land use (Lockwood, 2007; Novak and Seiler, 2001; Taylor *et al.*, 1995), zoning (Paulsen, 2011), and public spaces, such as parks and pedestrian paths (Chapin, 1991; Hilbron, 2009).

Few studies about the incidence of crime in Korea have been published by an international society (Chang, 2009; Yoon and Joo, 2005). These studies have focused only on crime determinants from a sociological perspective and have not investigated the determinants from a spatial planning perspective. Also, these studies are limited as they assumed that the covariates of crime do not vary in space. This assumption may be too much, as many previous studies on crime in diverse contexts have witnessed evidence of spatial dependencies and heterogeneities (Baller *et al.*, 2001; Browning *et al.*, 2010; Cahill and Mulligan, 2007; Hipp, 2007; Kim and Lee, 2011; Kim and Lee, 2013; Morenoff *et al.*, 2001). Many studies in Korea have failed to consider spatial heterogeneity in their analytical models. The present study investigated spatial factors affecting the incidence of crime while considering the spatial dependence of the incidence of crime. Also, the present study aimed to demonstrate location-specific characteristics of the relationship between spatial planning factors and the incidence of crime, which has long been of particular interest from a worldwide perspective.

2.3. Methodology and Data

2.3.1. Methodology

Theories to explain the causes of crime are largely divided into microscopic and macroscopic methods. Microscopic methods focus on the individuals or actors, while macroscopic methods place more

emphasis on social and structural factors. This categorization makes sense from the data structure viewpoint, as individual crime data are microscopic, while data on specific areas or nations are macroscopic. The spatial characteristics of the incidence of crime are critical when using macroscopic data on a regional scale. Crime is closely related to spatial characteristics and tends to concentrate in specific spaces due to spatial interaction or geographic dependence. Thus, the non-spatial model, such as the ordinary least square, may lead to biased and inconsistent estimates (Anselin, 1988).

Spatial autocorrelation is a method to validate the effectiveness of an empirical application of spatial econometrics models. Several indices are available for the autocorrelation test, but Moran's I, Geary's C, and Getis and Ord's G are the most widely used. The present study adopted Moran's I to test the spatial autocorrelation of the incidence of crime in our data. The results showed that the geographical dependence of violent crime incidence was significant at $p < .01$ (Table 2-1). This result shows that it is necessary to adopt spatial econometric models for the present study. Among the various spatial econometric models that incorporate the characteristics of spatial dependency, the present study adopted three representative spatial econometric models, such as the spatial autoregressive regression model (SAR), the spatial error model (SEM), and the spatial autoregressive confused model (SAC); their Durbin models, including the spatial Durbin model (SDM), the spatial Durbin error model (SDEM), and the spatial Durbin autoregressive confused model (SDAC), as well as the spatial lag of **X** (SLX) model are explained in the following section.

Table 2-1. Result of Spatial Autocorrelation Analysis

Year	Moran's I	p-value
2005	0.2266	0.0000
2010	0.1981	0.0000
2015	0.2467	0.0000

To identify spatial autocorrelation, it is important to define a spatial weight matrix, which represents the spatial effects. A spatial weight matrix defines spatial proximity based on the assumption that geographically adjacent areas have a high level of spatial interaction between them. The spatial weight matrix can vary in type. It is recommended to adopt a spatial weight matrix to verify whether the spatial effects are appropriately reflected by comparing the results from the application of diverse matrices. Thus, many studies that utilize spatial econometrics models have applied multiple spatial weight matrices in their empirical applications (Dubin, 1988; Can, 1992; Kim and Lee, 2013).

The present study adopted the inverse distance matrix. Due to the lack of data for rural regions, not all regions analyzed in this dissertation were adjacent. Therefore, it is not appropriate to utilize the contiguity matrix. The inverse distance matrix was formed based on distance, where $W_{ij} = 1/d_{ij}$. The weight matrices were row-standardized to avoid probable scale effects.

The standard spatial econometric models are the SAR, the SEM, and the SAC, which have been explained in detail by LeSage (1999). They are the same in their fundamental concept, but differ in the way they control spatial dependency and spatial autocorrelation.

The first model is the SAR as shown by Equation (1). This model assumes that observations adjacent to each other should reflect a greater degree of spatial dependence than those that are more distant, where Y is a $n \times 1$ vector of the dependent variable and X denotes a $n \times k$ matrix of the explanatory variables. W represents the spatial weight matrix containing distance. The scalar ρ is a coefficient on the

spatially lagged dependent variable, and β denotes a parameter vector estimated from the explanatory variables.

$$\begin{aligned} Y &= \rho WY + X\beta + \epsilon \\ \epsilon &\sim N(0, \sigma^2 I_n) \end{aligned} \qquad (1)$$

The second model is the SEM represented by Equation (2). This model is based on the assumption that the disturbances exhibit spatial dependence, where the scalar λ is a coefficient on the spatially correlated errors.

$$\begin{aligned} Y &= X\beta + u \\ u &= \lambda Wu + \epsilon \\ \epsilon &\sim N(0, \sigma^2 I_n) \end{aligned} \qquad (2)$$

The third model is the SAC represented by Equation (3), which includes both spatial lag and spatially correlated error terms. This model accommodates spatial dependence in both the dependent variable and error terms. The SAC model can be described in vector form by using the following two-stage formulation: W_1 and W_2 are two spatial weights matrices.

$$\begin{aligned} Y &= \rho W_1 Y + X\beta + u \\ u &= \lambda W_2 u + \epsilon \\ \epsilon &\sim N(0, \sigma^2 I_n) \end{aligned} \qquad (3)$$

In this study, Durbin type models of SAR, SEM and SAC and SLX models are also utilized. Durbin models can account for exogenous interaction effects in addition to the endogenous interaction effects (Lesage and Pace, 2009).

In this study, the SAR and SEM Durbin type models were used and the SAC and SLX models were also utilized. Durbin models account for the exogenous and endogenous interactive effects (Lesage and Pace, 2009).

The first Durbin type model is the SDM represented by Equation (4). Θ indicates the spatial correlation coefficient of the independent variables.

$$Y = \rho WY + X\beta + WX\theta + \epsilon$$
$$\epsilon \sim N(0, \sigma^2 I_n) \qquad (4)$$

The SDEM is represented by Equation (5). It accounts for spatial dependence among the error terms and the exogenous interactive effect.

$$Y = X\beta + WX\theta + u$$
$$u = \lambda Wu + \epsilon \qquad (5)$$
$$\epsilon \sim N(0, \sigma^2 I_n)$$

The SAC model can also be extended as the SAR and SEM models. The SDAC is represented by Equation (6).

$$Y = \rho W_1 Y + X\beta + W_1 X\theta + u$$
$$u = (I_n - \lambda W_2)^{-1}\epsilon \qquad (6)$$
$$\epsilon \sim N(0, \sigma^2 I_n)$$

The SLX model assumes no endogenous interactive effects or spatial dependence in the error terms. It only incorporates the exogenous interactive effects into the linear regression model. The SLX model is described in vector form as Equation (7).

$$Y = X\beta + WX\theta + \epsilon$$
$$\epsilon \sim N(0, \sigma^2 I_n) \qquad (7)$$

2.3.2 Data and Variables

This study investigated the incidence of violent crime in Korea during 2005, 2010, and 2015. The dependent variable of the study was violent crime as defined by the Supreme Prosecutors' Office of the Republic of Korea (SPO). Violent crime in this study refers to a broad range of acts of illegal violence encompassing murder, burglary, arson, sexual violence, assault, and kidnapping. Most previous studies used the crime rate as the primary indicator of the incidence

of crime. However, this study adopted the number of incidents of violent crime in an area as the dependent variable. Such an approach reflects the fact that the police deploy a force based on the number of occurrences of crime rather than the crime rate (Shin, 2019).

All variables applied in this study were selected based on the theoretical and empirical validity of previous studies and the availability of relevant data. The independent variables were categorized into demographic, socioeconomic, and spatial factors. The demographic variables included the population, the proportion of foreign residents, the proportion of seniors > 65-years-of-age, the proportion of females, the divorce rate at the regional level, and the percentage of single-person households. The socioeconomic variables included the proportion of the population with a college degree, the employment rate, the per capita local property tax, and the proportion of the population who had migrated from other regions. As data representing the economic status of the regions were not available, per capita property tax by region was adopted as an independent variable to denote the wealth of a region. The spatial variables included the ratio of hotel and restaurant establishments to the total number of businesses in the region and regional road accessibility.

Most of the independent variables were aggregated data derived from Statistics Korea, an official government agency. Using 2% randomly sampled microdata extracted from the Population and Housing Census by Statistics Korea, variables such as the immigration rate, the proportion of residents with a college degree, and the employment rate were adopted. The road accessibility data were derived from the Korea Transport Institute (KOTI).

The indicator of road accessibility was estimated based on Equation (8), where n represents the number of Korean regions and the KOTI-derived road accessibility of 247 regions. T_{ij} denotes the time spent between region i and region j passing through roads, and T_{ik} indicates the time required between region i and region k when using the roads. O_i represents the number of passengers whose

origin is region i, and D_i is the number of people whose destination is region i.

$$Road_i = \frac{1}{2(n-1)}\left(\sum_{j=1,j\neq i}^{n}\frac{O_i}{T_{ij}} + \sum_{k=1,k\neq i}^{n}\frac{D_i}{T_{ik}}\right) \quad (8)$$

Table 2-2. Description of Variables

Variables			Definition
Dependent Variable		VIO CRIME	Number of violent crimes occurred by region (Unit: 100 cases)
Independent Variables	Demographic Variables	POP	Population (Unit: 10,000 people)
		FOREIGN	Number of foreign residents (Unit: 1,000 people)
		OLD	Proportion of residents over 65 years
		FEMALE	Proportion of female population
		DIVORCE	Divorce rate
		S_HOUSE	Proportion of single-person households
	Socio-economic Variables	COLLEGE	Proportion of residents with a college degree
		EMP	Employment rate
		TAX	per capita property tax by region (Unit: 10,000 won)
		IMMIG	Proportion of residents migrated from other provinces
	Spatial Variables	ENTER	Proportion of restaurant and hotel establishments
		ROAD	Road accessibility

The ex-ante assumptions regarding the effects of the independent variables on the occurrence of violent crime provide useful insight. It is expected that the increase in the population will increase the number of crimes with a positive effect on the potential victims of crime (Andresen, 2006). Therefore, regions with larger populations would be faced with a higher incidence of crime. As

shown by Valier (2003), the size of the foreign population is likely to be positively associated with the level of crime. In Korea, problems associated with illegal stay or illegal employment tend to rise with economic development and status within the international community (Ha, 2017). Furthermore, the rate of increase in the crime rate of foreigners exceeded that of foreign residents in 2015 (Lee, 2020). However, some studies insist that the statistical association between the number of foreign residents and the rise in the crime rate is rather weak (Leiva *et al.,* 2020). As a result, the impact of a higher proportion of foreigners cannot be easily predicted. Crimes that target older adults are rising in Korea (Ko, 2016; Lee, 2010). The rate of gender-based violent crimes that target women is also rising drastically (Kim *et al.,* 2014). Crime is more frequent in socially disorganized areas, such as regions with a high divorce rate, due to the lack of a voluntary monitoring function (Cheong and Park, 2010; Lee and Lee, 2009; Sampson, 1985; Smith *et al.*, 2000). Thus, there is a likelihood that crime would be higher in regions where the proportions of older adults and women, and the divorce rates, are high. In Korea, the proportion of single-person households is continuously increasing and accounted for nearly 30% of all Korean households in 2019 (KOSIS). Choi and Park (2018) revealed a positive relationship between the proportion of single-person households and the occurrence of sexual violence. Violent crimes are more likely to occur within regions where the proportion of single-person households is higher.

Among the socioeconomic variables, the proportion of residents who are college graduates is likely to decrease the incidence of violent crime, as the cost of committing a crime is higher for highly educated people (Lauridsen *et al.*, 2013). Indicators of economic deprivation, such as the unemployment rate, often have strong and significant effects on the crime rate (Blau and Blau, 1982; Hooghe *et al.,* 2011; Messner, 1982; O'Brien, 1983; Sampson, 1985; Williams, 1984). Therefore, the likelihood of crime occurring would be higher

in regions with higher unemployment rates. Moreover, Choi and Park (2018) revealed an apparent relationship between poverty and the incidence of crime. The incidence of crime increases with deteriorating economic circumstances (Kwon and Jeon, 2016). Therefore, it is anticipated that violent crimes are less likely to occur in affluent neighborhoods. Some studies have shown that regions with a continuous inflow of migrants tend to have more crime (Lee and Choi, 2019; Warner and Pierce, 1993). However, Park (2018) insisted that the recurrent movement of the population weakens social exchange and the sense of belonging to a region, which lowers the possibility of collective action occurring to prevent crime. Accordingly, the direction of the effect of the proportion of migrants on the incidence of crime is uncertain.

Considering the spatial variables, this study assumed that the type of local industry is closely associated with the likelihood of crime. The proportion of hotel and restaurant establishments is likely to positively affect the incidence of burglary and sexual violence (Cheong, 2013). Lee and Cho (2006) also revealed the relationship between the regional industrial structure and the incidence of crime. Such findings suggest that violent crimes are more likely to occur in regions where hotels and restaurants are highly concentrated. The direction of the effect of road accessibility on the occurrence of crime is uncertain; a higher level of spatial accessibility may allow criminals to escape from a crime scene (Johnston and Bowers, 2010), but it may also boost crime prevention by facilitating preventive activities, such as police patrols (Cozens and Love, 2009).

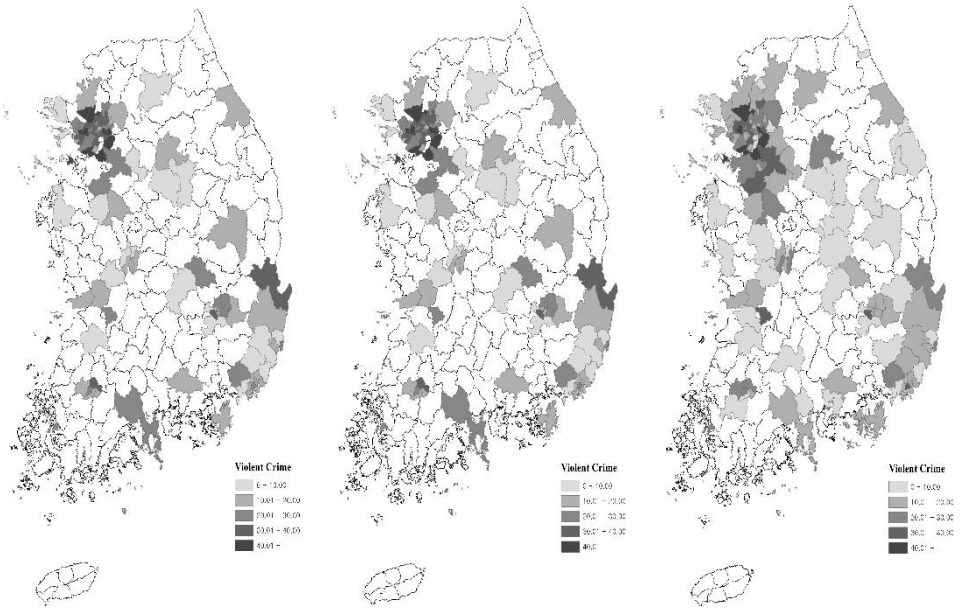
2.4. Results

2.4.1. Incidence of Violent Crimes in Korea

According to a survey carried out by Statistics Korea (2018), 20.6% of Koreans consider crime the most serious threat to their social security. A series of SPO internal data indicated that there

have been approximately 200,000 cases of violent crime per annum over the past 15 years (2005–2019) in Korea. The total number of violent crimes in 2005 was 299,615, and the number slightly decreased to 267,382 in 2019. On average, 279,333 incidents of crime occur annually. However, heinous crimes (murder, burglary, arson, and sexual violence) increased by 75.8% from 19,941 to 35,066 during the period. In general, the total number of violent crimes has been maintained with slight fluctuations, but heinous crimes have increased significantly during the last 15 years. This indicates a social trend that heinous crimes are becoming more frequent in Korea over time.

The incidence of violent crime varies by region in Korea. <Figure 2−1> presents the geographical distribution of violent crimes from 2005 to 2015. Due to the unavailability of data for rural regions, the focus of the analysis was narrowed to urban areas. In general, violent crimes are concentrated in the SMA and Southeastern Korea. Such a geographical tendency is likely to stem from the huge differences in population size by province.



2005 2010 2015

Figure 2-1. Violent Crime Incidence by Regions in Korea, 2005-2015

Since 2005, the region with the highest number of crimes has been Bucheon city located in SMA. A total of 6,781 cases of violent crime occurred in Bucheon in 2005. However, the most crime-prone area in 2010 and 2015 was Suwon city, also located in SMA. Gangnam-gu is one of the most affluent districts in Korea but ranked high in crime during 2010 and 2015.

Table 2-3. Top Five Regions for Violent Crime, 2005- 2015

	2005		2010		2015	
Rank	Region	Incidence	Region	Incidence	Region	Incidence
1	Bucheon	67.81	Suwon	63.76	Suwon	75.85
2	Suwon	67.75	Bucheon	58.94	Ansan	55.35
3	Seongnam	54.53	Seongnam	52.25	Seongnam	53.92
4	Goyang	49.24	Gangnam	46.98	Bucheon	52.93
5	Bupyeong	46.73	Goyang	43.21	Gangnam	46.70

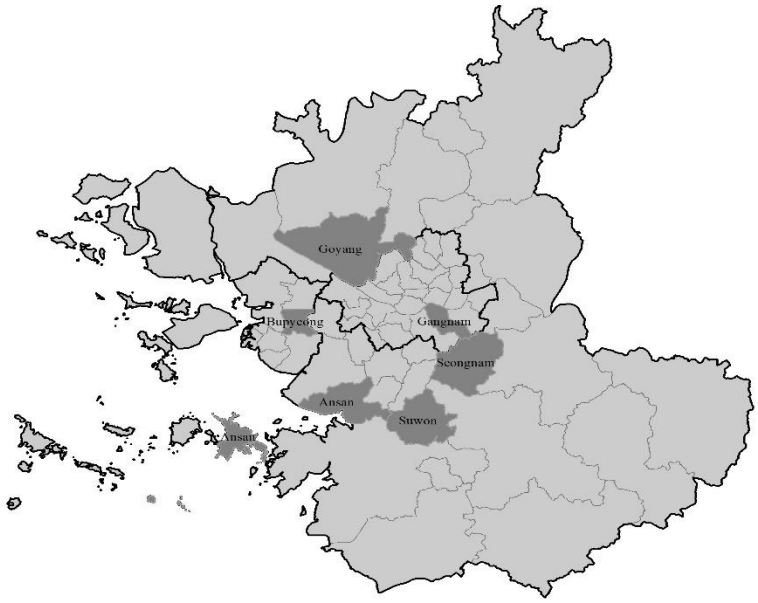


Figure 2-2. Top Regions for Violent Crime

<Table 2-4> shows the descriptive statistics for the variables. The average number of violent crimes among the study regions was 21.44 in 2005, and the number decreased continuously to 17.61 in 2015. In contrast, the proportion of foreign residents increased, comprising nearly 7% of the population. The proportion of older adults has also increased, as Korea has become an aging society. The ratio of female residents was constant at 51%. The divorce rate continuously decreased from 2.65 to 2.12 during 2005–2015. Such a trend reflects the fact that, in contrast to the 2000s, the change in the divorce rate stabilized in the 2010s (Kim and Yim, 2020). That said, the mean proportion of single-person households increased. More than one-quarter of residents in the subject regions were living alone in 2015.

The average proportion of the population with at least a bachelor's degree or higher has been increasing in Korea. This can be regarded as an improvement in the regional average educational attainment level. The average employment rate has also increased by more than 5% between 2005 and 2015m while the standard deviation decreased. Moreover, the average property tax per capita gradually

increased. In 2005, residents paid about KRW 57,000 in property taxes, but the amount increased to about KRW 155,500 in 2015. In particular, the standard deviation increased more than three times. One possible explanation is inflation, but it is more likely to reflect the aggravated property-value-related inequality among different regions. In contrast, the mean proportion of the population who have migrated from other provinces has decreased over time. This presents a social phenomenon of decreasing regional mobility.

The average ratio of hotel and restaurant establishments decreased throughout the analysis. In 2005, hotels and restaurants occupied about 20% of local businesses, but the proportion diminished by about 2.5% in 2015. Average road accessibility also decreased during the same period, but such an observation was related to the data obtained from the KNPA which are limited to relatively small cities.

Table 2-4. Descriptive Statistics of Variables

	2005				2010				2015			
Variables	Mean	S.D	Min	Max	Mean	S.D	Min	Max	Mean	S.D	Min	Max
Vio Crime	21.44	13.13	0.56	67.81	18.03	11.81	0.69	63.76	17.61	11.88	0.59	75.85
Pop	33.34	19.00	1.56	104.56	34.49	20.03	1.87	107.75	30.87	20.88	2.10	118.46
Foreign	3.24	3.04	0.11	18.23	6.19	6.81	0.11	38.97	6.92	8.31	0.18	55.72
Old	9.58	4.30	3.78	26.27	11.90	4.75	5.12	28.47	16.17	7.06	6.63	37.75
Female	51.08	1.11	47.37	53.8	51.28	1.13	48.08	53.42	51.31	1.29	45.17	54.01
Divorce	2.65	0.44	1.80	4.10	2.30	0.34	1.60	3.50	2.12	0.39	1.30	3.50
S_house	19.84	4.28	12.1	32.6	24.00	4.93	14.2	39.6	27.65	5.21	17.3	46.3
College	22.27	6.92	8.29	47.65	25.78	7.23	11.81	52.54	28.78	8.27	13.53	56.04
Emp	50.67	4.56	41.15	64.49	55.78	3.75	46.5	66	55.86	3.95	43.97	68.91
Tax	5.70	5.26	2.20	38.35	10.01	9.92	3.06	65.48	18.52	15.55	6.68	123.03
Immig	17.94	7.35	5.36	49.70	15.84	5.57	5.62	31.74	14.34	5.37	5.27	34.84
Enter	20.72	4.57	9.16	41.37	19.91	4.34	8.61	36.63	18.29	4.45	6.82	37.74
Road	0.72	0.72	0.02	3.73	0.72	0.72	0.02	3.74	0.61	0.69	0.02	3.74
N	116				116				145			

2.4.2 Determinants of Crime Victimization

<Table 2-5> shows the regression results of the SAR, SEM, and

SAC models[③]. The goodness-of-fit tests based on Akaike's Information Criterion and the Bayesian Information Criterion revealed that the SAC model possessed the highest explanatory power among the three models. However, the significance of rho, lambda, and the LM test result that assesses the presence of spatial dependence and autocorrelation support the validity of the SEM model during all three periods. For this reason, this study presents interpretations of the regression results solely focusing on the SEM model. The results show how the number of violent crime cases changed with the change in the independent variables. Although some results differed, the effects of the independent variables on crimes in Korea generally matched our expectations.

The number of inhabitants was positively associated with the incidence of violent crime ($p < .01$). The proportion of foreign residents was positively related to violent crime in 2010 and 2015, but not in 2005. In contrast, unlike the prior expectation, the proportion of older adults was negatively associated with violent crime. The proportion of females tended to be positively correlated with the incidence of crime, but no statistical difference was observed. As proposed by the social disorganization theory, the breakup of families can lead to a higher level of crime. This theory supports the observation in Korea that the number of divorcees had a positive effect on the incidence of crime. Furthermore, more violent crimes occurred where the ratio of single-person households was high. This finding agrees with the ex-ante expectation that single-person households are more vulnerable to crime.

Among the socioeconomic variables, the educational level of the residents was a significant determinant of violent crime during all periods. Employment had a negative effect on the incidence of violent crime in 2005 and 2010, but the sign turned positive in 2015 with no statistical significance. The per capita property tax had a positive effect on the incidence of crime, but no statistical significance was

[③] SAR, SEM, and SAC results of total crime and heinous crime are represented in <Appendix 1> and <Appendix 2>

detected. This finding indicates that the association between a region's level of wealth and the level of crime is uncertain. In contrast, the proportion of inhabitants migrating from other regions was negatively associated with the occurrence of violent crime ($p < .05$ dung all periods). Such a finding supports the statement that crimes are more frequent in regions with a stable inflow of a new population.

All of the spatial variables were positively correlated with the incidence of violent crime. The high concentration of hotel and restaurant establishments and better road accessibility had positive effects on crime. This observation suggests that the type of predominant business and the road accessibility level can make areas more vulnerable to violent crime.

Table 2-5. SAR, SEM, SAC Results of Violent Crime, 2005-2015

	2005			2010			2015		
	SAR	SEM	SAC	SAR	SEM	SAC	SAR	SEM	SAC
Intercept	-2.8068	-3.0448	-3.6090	-12.2411	-8.0030	-8.5127	-41.8765	-38.7392	-27.4129
Pop	0.4110***	0.3804***	0.3935***	0.3669***	0.3597***	0.3702***	0.3360***	0.3763***	0.3869***
Foreign	0.3275	0.2948	0.2973	0.2480**	0.2296**	0.2320**	0.3085***	0.2486***	0.2582***
Old	-0.6892***	-0.6273***	-0.6472***	-0.4405**	-0.3404*	-0.3977**	-0.5213***	-0.2733**	-0.3116***
Female	0.6039	0.6272	0.5858	0.6782	0.4818	0.4925	1.1237**	0.6027	0.5595
Divorce	-0.5787	0.9411	0.5036	-0.2962	1.0456	0.2732	0.7194	3.6870***	1.7989
S_house	0.2371*	0.1960	0.2184	0.2562**	0.2215*	0.2724**	0.1702*	0.1611**	0.1907**
College	-0.5362***	-0.5307***	-0.5497***	-0.6030***	-0.5273***	-0.5583***	-0.3469**	0.0129	-0.0671
Emp	-0.3664**	-0.3240**	-0.3424**	-0.3054*	-0.2010	-0.2558	-0.1065	0.0696	-0.0665
Tax	0.0599	-0.0280	0.0116	0.1188	0.0699	0.1015	0.0568	0.0051	0.0350
Immig	-0.3208***	-0.2567***	-0.2759***	-0.3159***	-0.2258**	-0.2900**	-0.2144**	-0.3044***	-0.3409***
Enter	0.1465	0.1945*	0.1942*	0.2862***	0.2694**	0.2709**	0.3169***	0.1092	0.1527**
Road	7.8351***	9.9315***	9.2727***	7.4036***	8.2897***	7.4167***	4.7306***	3.6693***	2.3459**
ρ	0.4038***		0.2352	0.3339**		0.3195*	0.0429		0.2209**
λ		0.8470***	0.7616***		0.6567**	0.5071		-3.4268***	-3.8880***
LM(lag)	13.37***		1.42	5.23**		4.28**	0.09		6.56**
LM(error)		52.32***	13.29***		5.52**	2.45		4.04**	6.74***
AIC	717.3455	712.0702	712.8925	711.2050	712.3331	711.3988	843.8450	834.2185	830.8170
SBC	758.6493	753.3741	756.9499	752.5088	753.6370	755.4562	888.4960	878.8695	878.4447
N		116			116			145	

* p<.1, ** p<.05, *** p<.01

<Table 2-6> shows the results of the SDM, SAR, SEM, SAC, and SLX models[④]. The SDM and the SLX models accounted for the exogenous and endogenous interactive effects. The SDAC model exhibited the highest explanatory power among the models during 2005 and 2015, whereas the results of rho, lambda, and the LM test were significant in the SDEM model during all periods. Therefore, this chapter focused on interpreting the results based on the SDEM model.

Most of the endogenous effects presented similar results. However, the divorce rate was negatively associated with crime in contrast to that of the basic spatial linear regression models but no statistical significance was detected. The proportion of single-person households had a negative effect on the incidence of crime in 2005 although it lacked statistical significance. As most of the independent variables presented analogous endogenous effects, this section mainly discusses the exogenous effects.

Among the demographic variables, population had a negative effect on the incidence of crime in 2005, but a positive association was observed for cases in 2010 and 2015, indicating that an increase in population in one region could lead to a higher incidence of crime in adjacent areas. The proportion of foreign residents had a positive exogenous effect in 2005 and 2010, but the effect became negative in 2015 ($p < 0.1$). Unlike the endogenous effect, the ratio of the older population positively affected the incidence of crime in adjacent regions during 2010 and 2015. The rise in the number of female inhabitants had a positive effect in 2005 and 2010, but a negative effect was found in contiguous areas in 2015. The divorce rate negatively affected the incidence of crime in adjacent areas as an endogenous effect, but it positively affected other regions in 2015. The proportion of single-person households negatively affected the occurrence of violent crime in adjacent regions during all years.

④ SDM, SDEM, SDAC and SLX results of total crime and heinous crime are represented in <Appendix 3> and <Appendix 4>

he proportion of residents with at least a bachelor's degree had a negative effect on the incidence of violent crime in contiguous regions during 2005 and 2010, but such an effect was positive ($p < .01$) in 2015. The employment rate and the mean property tax per person had a negative effect on the occurrence of violent crime in 2010. However, these variables positively affected other regions in 2005 and 2015. The increase in the proportion of residents migrating from other provinces negatively affected the incidence of crime in contiguous areas regardless of the time.

The proportion of hotel and restaurant establishments negatively affected the occurrence of violent crime in adjacent regions during all years. However, improvements in road accessibility in one area caused more crime in neighboring cities.

Table 2-6. SDM, SDEM, SDAC, SLX Results of Violent Crime, 2005-2015

	2005				2010				2015			
	SDM	SDEM	SDAC	SLX	SDM	SDEM	SDAC	SLX	SDM	SDEM	SDAC	SLX
Intercept	−373.406	−430.760*	−247.868	−432.120	−524.794	−437.689	−394.927	−391.394	231.371	799.899**	705.213**	441.598
Pop	0.3700***	0.3547***	0.3699***	0.3650***	0.4109***	0.4237***	0.4221***	0.4035***	0.3231***	0.3187***	0.3304***	0.3008***
Foreign	0.2592	0.5741**	0.4358	0.3228	0.3003***	0.2822***	0.2775***	0.2849***	0.3107***	0.3198***	0.3039***	0.3425***
Old	−0.6650***	−0.7985***	−0.7389***	−0.6959***	−0.5058***	−0.4501***	−0.4427**	−0.4767***	−0.4822***	−0.5572***	−0.5071***	−0.5505***
Female	0.9697*	1.3494**	1.0743**	1.1070*	0.8344	0.5517	0.5107	0.6805	0.7957**	0.9953**	0.8527**	0.8694*
Divorce	1.4802	−0.0813	0.4841	1.1162	−1.4520	−0.7330	−0.6890	−1.3348	0.6187	−0.0962	0.3095	−0.4858
S_house	0.0664	−0.0236	0.0663	0.0327	0.2432**	0.2589**	0.2600**	0.2458**	0.1162	0.1203	0.1221	0.1119
College	−0.6154***	−0.8017***	−0.7213***	−0.6478***	−0.7351***	−0.6551***	−0.6488***	−0.7160***	−0.3336***	−0.4398***	−0.3828***	−0.4510***
Emp	−0.1951	−0.3189**	−0.2646*	−0.2187	−0.2242	−0.2320	−0.2356	−0.2372	−0.1711*	−0.1231	−0.1515	−0.1920
Tax	−0.0672	0.0377	0.0166	−0.0513	0.1818**	0.1657**	0.1620**	0.1691**	0.0428	0.0519	0.0447	0.0615
Immig	−0.3229***	−0.3549***	−0.3375***	−0.3326***	−0.4132***	−0.4133***	−0.4087***	−0.3956***	−0.2996***	−0.2461***	−0.2774***	−0.2540***
Enter	0.2091*	0.3017**	0.2773**	0.2059	0.3026***	0.2336**	0.2285**	0.2932***	0.3372***	0.3373***	0.3289***	0.4088***
Road	10.9478***	10.8867***	10.7071***	10.8595***	6.0094***	5.1366***	5.1942***	6.2979***	5.8767***	6.3076***	6.1437***	6.3091***
W_pop	−0.3083	−0.3577	−0.5755	−0.1745	0.7991	0.6337	0.5666	0.5372	2.3032***	0.2821	1.9016***	0.4389
W_foreign	−4.4868	5.1490	1.5602	−2.7148	0.9796	1.4156	1.2877	0.4571	−0.0519	−0.8843*	−0.1404	−1.1677*
W_old	−3.3602	−6.0422**	−4.0358	−4.0684	−1.1946	0.2192	0.4013	−0.7375	2.0291*	4.6331***	4.0051***	3.1150**
W_female	8.9285	19.7639***	13.1343**	11.484	13.2511*	11.0578*	10.1938	10.5582	−5.8390	−15.5794***	−14.6224***	−8.059
W_divorce	−25.7394	−77.2937***	−58.3395***	−33.7462*	−39.0389**	−36.5552**	−36.6371**	−39.9757**	22.1577*	21.2863**	33.1991***	3.5654
W_s_house	−1.1914	−4.1547**	−3.3601**	−1.6637	−1.7273	−2.5628**	−2.5893**	−1.7217	−1.0050	−2.6844***	−1.8334**	−2.4064**
W_college	−0.4960	−5.2961*	−3.6212	−1.1709	−2.0510	−0.9627	−0.8617	−1.7593	2.3302**	3.1292***	3.4538***	1.8264
W_emp	3.7042*	−0.0119	0.5162	3.3578	1.2635	1.3737	1.3965	1.4272	−0.2372	−2.1668*	−1.9195*	−0.6592
W_tax	−4.4683*	−1.6964	−3.0146	−3.8577*	0.3671	1.1278	1.0662	0.0437	−0.4478	−0.7124*	−0.6473*	−0.7089
W_immig	−2.3830*	−3.4101***	−2.6666**	−2.6178**	−3.8458**	−4.4708***	−4.3596***	−3.3962**	−2.0317**	−0.8735*	−2.3022***	−0.5309
W_enter	−4.8194***	−4.8870***	−4.3563**	−5.0688***	−1.0470	−0.7450	−0.8308	−1.4438	−1.5121	−1.5697*	−1.1809	−2.4142**
W_road	32.9479**	32.2146**	32.252**	33.2838**	17.794	6.0268	5.9393	17.6953	15.4419	14.7535	21.8056**	11.151
ρ	0.4437		0.6882***		−0.4867		0.1198		−4.0960***		−3.2614***	
λ		−2.3525**	−2.7412***			−2.3629***	−2.4450***			−4.2098***	−3.4539***	
LM(lag)	1.94		8.48***		0.8		0.06		19.12***		10.92***	
LM(error)		1.8	5.08**			4.91**	4.28**			16.23***	7.72***	
AIC	699.6751	697.6706	693.5048	699.3824	699.6018	692.7687	694.7064	698.4830	809.3654	812.7695	797.2012	839.2626
SBC	774.022	772.0175	770.6053	770.9758	773.9488	767.1156	771.8069	770.0764	889.7372	893.1413	880.5497	916.6576
N	116				116				145			

* p<.1, ** p<.05, *** p<.01

2.5. Summary

Criminal policy should focus more on possible preventive measures, rather than the post-hoc follow-up after an incident (Ha, 2017; Kim and Lee, 2011). This study investigated the determinants of violent crime in Korea, focusing particularly on spatial planning effects on crime. As the incidence of crime is closely related to the spatial characteristics of a city, spatial econometrics models were applied to incorporate regional characteristics into the statistical models. The major spatial variables adopted in this study were the proportion of hotel and restaurant businesses and road accessibility.

The major findings of this study are summarized as follows. First, population size and the proportion of foreign residents were important factors identifying the incidence of violent crime, suggesting that more foreigners and women reside in areas where the level of violent crime was higher. The increase in single-person households led to more violent crimes. As regions with single-person households are vulnerable to crime, it is recommended to reinforce the surveillance and security systems in the areas where this type of housing is concentrated.

Second, the effect of spatial variables that identify violent crime proved to be highly effective. The increase in the number of hotel and restaurant businesses was positively associated with the incidence of crime. This is probably because the use of these industries leads to increased consumption of alcoholic beverages, which can provoke people to commit a crime. In addition, enhancement of the road accessibility has a positive effect on crime.

This chapter concludes that since the crime prevention strategies should be based on the locality of the region, the results of this chapter can provide basic information to incorporate idiosyncratic characteristics of local areas that are suitable for establishing crime prevention strategies.

Chapter 3. Determinants on Violent Crime Hot Spots: Application of Spatial Discrete Choice Model

3.1. Introduction

According to the list of violent crime rates per 100,000 persons in OECD member countries as of 2018, Korea was ranked 25th in murder rate (OECD). Seok (2012) also compared the total crime rates among major advanced countries and demonstrated that the total crime rate for Korea has been rising while those of other countries, including the U.K., the U.S., Germany, France, and Japan, are showing a decreasing trend. The rapid industrialization and the consequent urbanization seem to have rendered such crimes to become more frequent and heinous, and as a result, the demand for powerful and effective crime prevention measures is increasing.

Several previous studies suggest that crimes are not evenly distributed over urban areas. Instead, crimes tend to cluster in small places, or so-called hot spots, where a half of all criminal events are being generated (Pierce et al., 1988; Sherman et al., 1989; Weisburd et al., 1992). Many researchers highlighted that the level of crime incidents can be reduced if police officers give more attention to such areas (Braga and Weisburd, 2010; Eck, 2002; Kim and Lee, 2013; Weisburd, 2008). These studies fundamentally challenge the efficiency of the random police patrolling practices, emphasizing that it is more effective to concentrate the patrolling efforts on strategically selected crime-prone areas. Such finding is supported by several studies on crime hot spots (Braga et al., 2012; Braga, 2005; Byrne, 2008; Kim and Lee, 2013; Lee, 2008; Rosenbaum, 2006; Tonry, 2011;).

Conventional crime theories and relevant discussions have apparently focused on criminal motives, or reasons, of criminals. A number of studies have been carried out, focusing on individuals to investigate not only criminal reason or motives, but factors deterring crimes as well. However, since the 1970s, with the appearance of a

new theory, crime opportunity theory, researchers began to take crime opportunities into account which spurred the efforts to explain crime incidents and damages in both microscopic and macroscopic perspectives (Meier and Miethe, 1993). Particular attention has been paid to environmental criminology, which explains the relationship between space and crimes based on crime opportunity theory (Meier and Miethe, 1993). This perspective investigates factors such as site characteristics, status of informal and formal surveillance, and other aspects of built environment that compose the area.

Environmental criminology lies at the intersection of criminology, sociology, and geography and focuses on the spatial distribution of crime, criminals, targets, and the interaction between these components (Brantingham and Brantingham, 1981). A great deal of studies, including Jacobs (1961), Jeffery (1971), Newman (1973), and Brantingham and Brantingham (1975; 1981), popularized the idea that the built environment of an area could influence criminality. Spatial impacts on crime hot spots can be controlled by spatial planning practices in conjunction with multi-dimensional government intervention. Although it is impossible to form a spatial planning practice reflecting all the spatial impacts, key factors closely related to crime incidence can be thoroughly managed by spatial planning practitioners. In this regard, it is highly urgent to investigate the relationship between probability of crime and spatial boundary of crime incidence that can be represented by crime hot spots in the urban planning perspective.

Hot spots have everything to do with the place and thus the term refers to the areas that tend to have more crimes than other areas. A crime hot spot is generally defined as a small area or location where crime incidence is concentrated in (Anselin et al., 2000) or a place where crimes occur progressively and repeatedly (Alex and Kate, 2001). From this definition, crime hot spots can be expressed in a discrete form when using aggregated data, where areas are categorized into crime hot spots whose value is 1 and other areas with value of 0. Subject to spatial dependence, crime tends to

spatially gather in certain spaces and so do crime hot spots. With all things taken together, it is desirable to adopt a spatial econometrics model to reflect the properties of the crime hot spots that are matched with statistical traits of discrete dependent variable.

3.2. Background

Who commits crimes? This question is frequently used to be the main question raised in criminal studies. However, the focus has gradually been shifted from "who" to "what." In other words, more attention is being driven to environmental factors such as buildings and residential environment to mitigate crime or fear of crime through adjusting environmental factors. This implies that physical environment is one of the major factors for crime occurrence, which is the fundamental premise of environmental criminology.

Environmental criminology examines the link between crime and physical location, while explaining how human activities are spatially shaped (Brantingham and Brantingham, 1984). Deeply rooted in the urbanism and human ecology (Palen, 2012), environmental criminology explains crime, criminality, and victimization related to place, space, and their interaction, especially in urban settings. The goal of this school is to identify ways to manipulate attributes of physical environment to reduce the opportunities of crime at various points in time (Kim et al., 2012).

Environmental criminology has its roots in social disorganization theory developed by Shaw and McKay (1942). Crime studies based on social disorganization theory mainly deal with characteristics of demographic, social, and economic environments but commonly neglect the fact that the physical environment of neighborhoods can affect crime in the corresponding areas. Research on the relationship between crime and physical environment was initiated by Jacobs (1961), who suggested urban planning approaches to prevent crimes, and then full-fledged research efforts were followed by defensible space theory by Newman (1973) and crime prevention through

environmental design (CPTED) by Jeffery (1971). These two monumental theories of crime suggest various crime prevention strategies based on similar theoretical criteria, including surveillance, access control, and territorial reinforcement. However, both theories also neglect the characteristics of the entire physical environments such urban forms as density, concentration, accessibility, etc.

Research on the relationship between urban physical environment and crime has been mainly conducted by Cohen and Felson (1979), who introduced the routine activity theory that focuses on situations of crimes to identify drivers of crime. They insisted that crime opportunities are formed by the confrontation of routine living areas of criminals and potential victims. Although this theory focuses on the locations closely related with living areas to identify the relationship between crime and physical environments, it also has a limitation that it cannot reflect physical factors, including land use and location of residential areas.

The importance of diverse characteristics of physical environment on criminology research is intensively supported by the perspective of environmental criminology propagated mainly by Brantingham and Brantingham (1975, 1981, 1993). They introduced new concepts that consist of diverse urban forms, including node, path, edge, and environmental backcloth, to explain the effect of the physical characteristics on crimes. These concepts are quite similar to the factors of urban form, as suggested by Kevin Lynch (1960), and accentuate the importance of factors in urban planning that mainly investigates the physical characteristics of urban spaces. There have been a number of empirical studies that investigate the relationship between urban planning factors and crime incidence based on the environmental criminology perspective. Spatial factors that have earned much of the research interests were spatial connectivity (Cozens and Love, 2009; Hiller and Shu, 2000; Johnston and Bowers, 2010), mixed land use (Taylor et al., 1995; Novak and Seiler, 2001; Lockwook, 2007), zoning (Paulsen, 2011), and public spaces, such as parks and pedestrian paths (Chapin, 1991; Hilbron,

2009).

In applied sciences, a prominent theoretical argument should be in parallel with a suitable method when it tries to secure its academic domain. There have been interdisciplinary efforts in the fields of geography, urban planning, and criminology to address the causal relationship between physical environment and crime incidence. The relationship between crime and place is neither uniform nor static. As discussed before, crime incidence tends not to be randomly scattered over space but is clustered in certain areas. This concentrated pattern of crime incidence requires researchers to take two spatial phenomena into consideration, that is, spatial dependence and spatial heterogeneity (Anselin, 1988), if they want to investigate the causes of crime incidence using aggregated data.

Spatial dependence refers to the most common form of spatial effect, in which events in a location influence other events in other locations. Spatial heterogeneity, another form of spatial effect, implies that the stability of relationships may vary depending on geographical characteristics such as size, adjacency, etc. As one of the pioneering scholars in this field, Anselin (1988) proposed a way of identifying spatial effects in diverse empirical settings. More recently, huge efforts have been made to explore the local effects of independent variables that affect crime incidence to correct the statistical caveats of spatial heterogeneity (Brownning et al., 2010; Cahill and Mulligan, 2007; Graif and Sampson, 2009; Hipp, 2007; Hooghe et al., 2011).

The present chapter aims to investigate the effects of spatial planning variables on identifying the crime hot spots. The following section explains the spatial econometrics models that are suitable for our data when spatial dependency and spatial heterogeneity are assumed to be present.

3.3. Methodology and Data

3.3.1. Methodology

The purpose of this chapter is to investigate the regional factors that give rise to violent crime hot spots[5]. To do so, it is required to decide the level of the crime hot spots. To identify the violent crime hot spots, the LISA (Local Indicator of Spatial Association) technique was applied to detect crime hot spots suggested by Anselin (1995). LISA is a methodology that searches hot spot clusters based on the numerical similarity of attribute values among neighboring regions. The LISA identifies four types of areas: high values surrounded by other high values (high-high), low values surrounded by other low values (low-low), low values surrounded by high values (low-high spatial), and high values surrounded by low values (high-low).

Among the four types of areas, high-high and high-low areas are generally designated as the hot spots. Baumont et al. (2004) and Boots and Nelson (2008) extended hot spots from high-high areas to include high-low areas, while some studies strictly defined high-high areas only as hot spots (Moons et al., 2009). In this chapter, high-high areas are solely treated as the hot spots to clearly differentiate the violent crime hot spots from other areas.

To identify spatial autocorrelation, it is important to define a spatial weight matrix, which represents the spatial effects. Spatial weight matrix defines spatial proximity based on the assumption that geographically adjacent areas have a high level of spatial interaction between them. The spatial weight matrix may vary in its types. Generally, it is recommended to adopt a spatial weight matrix to verify whether the spatial effects are appropriately reflected by comparing the results from the application of diverse matrices. For that reason, many studies utilizing the spatial econometrics models have applied multiple spatial weight matrices (Can, 1992; Dubin, 1988). Since not all subject regions are attached to each other, the present chapter adopts an inverse distance matrix. The weight matrixes were row-standardized to avoid scale effects.

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[5] Violent crime in this study refers to a broad range of acts of illegal violence encompassing murder, burglar, arson, sexual violence, assault, kidnapping, and so forth.

The present chapter aims to identify the relationship between violence crime hot spots and regional factors. The dependent variable (crime hot spots) is discrete, where a crime hot spot is denoted as 1 and 0 otherwise. Generic spatial econometrics models that are compatible with discrete dependent variables include spatial logit, spatial probit, and spatial Tobit. To identify the determinants of crime hot spots, the present chapter adopts Spatial Autoregressive Probit Model (SAPM) and Spatial Error Probit Model (SEPM).⑥

The normal maximum likelihood spatial econometrics techniques are not suited to a binary dependent variable, because the probit probabilities do not have a closed form and therefore require numerical approximation (Anselin, 2002). Bayesian methods represent a better approach to the traditional spatial probit, as they are flexible and accommodate both SAPM and SEPM (Lesage and Pace, 2009). These methods use a Markov Chain Monte Carlo (MCMC) approach to estimate the parameters of the model (Lesage and Pace, 2009).

In expanding the binary choice decision to accommodate spatial dependence, the SAPM is expressed as in Equation (1).

$$\begin{aligned} Y &= \begin{Bmatrix} 1 \text{ if } Y^* > 0 \\ 0 \text{ if } Y^* \le 0 \end{Bmatrix} \\ Y^* &= \rho W Y^* + X\beta + \varepsilon, \varepsilon \sim N(0, \sigma^2 V) \\ V &= diag(v_1, v_2, \cdots, v_n) \end{aligned} \quad (1)$$

ρ denotes the spatial autoregressive parameter that measures the spatial lag of the latent variable estimate, and I is the unit diagonal identity matrix. W denotes the spatial weight matrix. As heteroskedasticity (represented Y, V) is often present in spatial models of probit estimation, this chapter applied a Baysian spatial probit estimation with the Gibbs sampler suggested by LeSage

⑥ Anselin (2002) mentioned distinctive ways to model spatial dependence in the discrete choice models. Comparing probit and logit frameworks, he noted that the spatial probit has an advantage over the spatial logit because the error term is analytically intractable in the latter.

(1999).

The SEPM can be written as in Equation (2). The difference between SAPM and SEPM is whether the spatial dependence is controlled by $\mathbf{Y}$ or $\mathbf{u}$. Here, λ is a coefficient on the spatially correlated errors.

$$\begin{aligned} Y^* &= X\beta + u \\ u &= \lambda W u + \varepsilon, \varepsilon \sim N(0, \sigma^2 V) \\ V &= diag(v_1, v_2, \cdots, v_n) \end{aligned} \qquad (2)$$

The correct interpretation of the estimated coefficients in SAPM involves a computation of direct, indirect, and total effects. These computations are intensively explained in LeSage and Pace (2009), so this chapter will not reiterate these points here. The direct effect characterizes the average impact of a change in the explanatory variables on the dependent variable at the same location. The indirect effect characterizes the average impact of a change in the explanatory variables on the dependent variable in different locations. The total effect represents the sum of direct and indirect effects.

The SAPM model expressed in Equation (1) is rewritten to its reduced form as Equation (3) through which the direct and indirect effects can be obtained.

$$Y^* = (\mathrm{I} - \rho \mathrm{W})^{-1} X\beta + (\mathrm{I} - \rho \mathrm{W})^{-1} \varepsilon \qquad (3)$$

The matrix of partial derivatives of the expectation of $Y, E(Y)$ with respect to the k^{th} explanatory variable of X is,

$$\frac{\partial E(Y^*)}{\partial x_{ik}} \cdots \frac{\partial E(Y^*)}{\partial x_{nk}} = (\mathrm{I} - \rho \mathrm{W})^{-1} \beta_k \qquad (4)$$

The diagonal elements of Equation (4) represent direct effects, while the off-diagonal elements contain the indirect effects. Accordingly, the direct and indirect effects can be expressed as Equation (5):

$$\text{Direct effect}: \frac{\partial y_i^*}{\partial x_{ik}} = S_k(W)_{ii}$$
$$\text{Indirect effect}: \frac{\partial y_i^*}{\partial x_{ik}} = S_k(W)_{ji}, \forall\, i \neq j \quad (5)$$

where $S_k(\mathrm{W}) = (\mathrm{I} - \rho\mathrm{W})^{-1}\beta_k$ act as a "multiplier" matrix that applies higher-order neighboring relations to X_k.

3.3.2 Data and Variables

The analysis is conducted using data from 2005, 2010, and 2015. It might be more reasonable to use recent datasets or to conduct a dynamic time-series analysis from the past to the present but relevant data was not available at the time of analysis. Data from the Supreme Prosecutors' Office (SPO) and the National Police Agency (KNPA) of Korea are not collected at a lower level of administrative units, especially on rural areas, and as a result, the study areas are limited to urban cities.

All the variables adopted in this chapter are selected regarding the theoretical validity supported by previous studies and the availability of relevant data. The dependent variable is whether the applicable area is a hot spot of violent crime.

The independent variables are categorized into three groups: demographic, socio-economic, and spatial variables. Demographic variables are population, the proportion of foreigners, and the proportion of female residents. Socio-economic variables are the proportion of the population graduated from at least a college, the employment rate, and the proportion of residents living in their own houses. Spatial variables are the ratio of the hotel and restaurant establishments to the total number of businesses in the study regions and the regional road accessibility.

Most of the independent variables are aggregated statistics data obtained from Statistics Korea, an official government agency. Variables including the proportion of residents with a college degree, the employment rate, and the proportion of residents living in their

own housing are based on the 2% Population and Housing Micro Data collected by the same agency. The data on road accessibility was obtained from the Korea Transport Institute (KOTI).

The indicator of road accessibility was estimated based on Equation (3). In this equation, n represents the number of Korean regions and KOTI derived road accessibility with 247 regions. T_{ij} denotes the time spent between region i and region j passing through roads and T_{ik} indicates the time required between region i and region k when using roads. O_i represents the number of passengers whose origin is region i and D_i means the number of people whose destination is region i.

$$Road_i = \frac{1}{2(n-1)}\left(\sum_{j=1,j\neq i}^{n}\frac{O_i}{T_{ij}} + \sum_{k=1,k\neq i}^{n}\frac{D_i}{T_{ik}}\right) \quad (6)$$

A set of expectations with respect to the effects of the independent variables on determining violent crime hot spots was constructed prior to the analysis. The increased population size is expected to increase the number of crimes, and as such, it is likely to have a positive association with potential victims of crimes (Andresen, 2006). Therefore, it can be reasonably assumed that there is a high possibility of being a violent crime hot spot for regions with a larger population. According to Valier (2003), the concentration of foreign population has a positive association with the crime occurrence level. In Korea, foreigner-related problems, such as illegal stay or illegal employment, have risen with the progress in economic development and the attainment of a higher status in the international society (Ha, 2017). Furthermore, the rate of increase in the crime rate by foreigners exceeds that of foreign residents in 2015 (Lee, 2020). However, some existing studies doubt any statistical association between the increase in the number of foreign residents and the rise in the crime rate (Kim et al., 2012; Leiva et al., 2020). Thus, it is not easy to predict the effect of the high ratio of

foreigners on the likelihood of crime hot spots. Meanwhile, the proportion of female victims of violent crimes has been drastically rising (Kim et al., 2014). The possibility of formation of crime hot spots in a region is expected to be higher where the proportion of women is greater.

Among the socio-economic variables, the proportion of residents with a college degree is expected to negatively affect the occurrence of crime incidents since the opportunity cost of committing a crime is higher for the highly educated people (Lauridsen et al., 2013). Indicators of economic deprivation, such as unemployment, are often found to have a strong impact on the crime rates (Blau and Blau, 1982; Hooghe et al., 2011; Messner, 1982; O'Brien, 1983; Sampson, 1985; Williams, 1984). Choi and Park (2018) revealed that there is an apparent relationship between poverty and the incidence of crimes. The crime incidence tends to increase with deteriorating economic circumstances (Kwon and Jeon, 2016). Meanwhile, home ownership is a fundamental component of stability in life, and it is usually realized by a means of income (Hwang and Lee, 2012). Thus, the ratio of residents living in their own housing was selected as a proxy variable of income. It is anticipated that the possibility of falling into a crime hot spot will be lower for regions where a high proportion of people reside in their own houses.

Considering the spatial variables, the ratio of hotel and restaurant establishments usually has a strong impact on burglar and sexual violence (Cheong, 2013). Lee and Cho (2006) also revealed a close relationship between crime incidence and the regional industrial structure. According to the authors, violent crimes are more likely to transpire in a region where the proportion of hotel and restaurant establishments is high. Better spatial accessibility is expected to either allow criminals to escape quickly (Johnston and Bowers, 2010) or facilitate crime prevention activities, such as police patrol (Cozens and Love, 2009).

Table 3-1. Description of Variables

Variables			Definition
Dependent Variable		Violent Crime Hot Spot	Whether the region is a hot spot for total crimes
Independent Variables	Demographic Variables	POP	Population (Unit: 10,000 people)
		FOREIGN	Number of foreign residents (Unit: 1,000 people)
		FEMALE	Proportion of female population
	Socio-economic Variables	COLLEGE	Proportion of residents with a college degree
		EMP	Employment rate
		OWN	Proportion of residents living in their own houses
	Spatial Variables	COMMER	Rate of restaurants and hotels business of the region
		ROAD	Road accessibility of the region

3.4. Results

3.4.1. Crime Hot Spots in Korea

According to LISA analysis, there were 38 areas identified as violent crime hot spots in 2005, and the number increased to 39 in 2010. Contrary to 2005, one city in Gangwon province was included. In 2015, the number of hot spots of violent crimes slightly increased to 42. However, if the total number of areas is considered, the ratio of hot spots seems to have diminished over time. One of the findings that warrants attention is that most of the crime hot spots are located in Seoul Metropolitan Area (SMA).

2005 2010 2015

Figure 3-1. Hot Spots for Violent Crime

<Table 3-2> denotes the descriptive statistics of variables. The average population had reduced by 25,000 between 2005 and 2015. This is due to the data of small cities that were added in 2015. The mean proportion of foreign residents had continuously increased reaching nearly 7% by 2015. The mean proportion of female residents has been generally constant with a slight fluctuation.

Among the socio-economic variables, the mean employment rate shows an increasing trend. Between 2005 and 2015, the rate rose by more than 5%. The average proportion of residents with a college degree is also increasing. In 2015, about 28% of people were graduates of a college. Furthermore, the mean ratio of residents living in their own houses rose during the same period by around 3%.

The mean proportion of hotel and restaurant establishments had decreased from 2005 to 2015. In 2005, over 20%of local businesses were hotel and restaurant establishments, but the proportion had diminished by about 2.5%in 2015. The average road accessibility had

also decreased during the same period. It might be related to the limitation of data obtained from KNPA that are derived from relatively small cities.

Table 3-2. Descriptive Statistics of Variables

	2005				2010				2015			
Variables	Mean	S.D	Min	Max	Mean	S.D	Min	Max	Mean	S.D	Min	Max
Pop	33.34	19.00	1.56	104.56	34.49	20.03	1.87	107.75	30.87	20.88	2.1	118.46
Foreign	3.24	3.04	0.11	18.23	6.19	6.81	0.11	38.97	6.92	8.31	0.18	55.72
Female	51.08	1.11	47.37	53.8	51.28	1.13	48.08	53.42	51.31	1.29	45.17	54.01
College	22.27	6.92	8.29	47.65	25.78	7.23	11.81	52.54	28.78	8.27	13.53	56.04
Emp	50.67	4.56	41.15	64.49	55.78	3.75	46.50	66.00	55.86	3.95	43.97	68.91
Own	60.79	7.68	43.17	82.65	60.01	9.43	38.32	82.04	63.84	10.33	39.11	87.58
Commer	20.72	4.57	9.16	41.37	19.91	4.34	8.61	36.63	18.29	4.45	6.82	37.74
Road	0.72	0.72	0.02	3.73	0.72	0.72	0.02	3.74	0.61	0.69	0.02	3.74
N	116				116				145			

3.4.2. Determinants of Crime Hot Spots

<Table 3-3> presents the regression results of the SAPM and SEPM models. Two spatial econometric models that reflect spatial dependence and spatial autocorrelation present similar results. The results of the SAPM model hold a marginal significance at $p < .01$, whereas the SEPM model has become significant when socio-economic and spatial planning variables are controlled. Therefore, this study focuses on the interpretations of the regression results based mainly on the SAPM model with respect to the direct and indirect effects of the independent variables. The probability of effects of the independent variables on determining crime hot spots in Korea is generally in line with the expectations, but nonetheless, there were some noticeable disparities.

All the demographic variables were proved to be statistically significant in determining violent crime hot spots. The larger the floating population in an area, the greater the prevalence of crime incidents (Lee and Cho, 2006). The size of the population increases

the probability of becoming a hot spot for violent crimes. The proportion of foreign residents also increases the chance to form a crime hot spot. The proportion of female residents had a negative effect on such a likelihood in the case of 2005, but the effects were positive in 2010 and 2015 with statistical significance.

Among the socio-economic variables, the employment rate was shown to have a negative impact in 2005 and 2010. However, the impact then turned positive in 2015 without a statistical significance. The other two variables, namely, the proportion of residents with a college degree and those living in their own houses, have negative impacts on the likelihood to become a hot spot for violent crimes with statistical significance at $p < .10$.

The proportion of hotel and restaurant establishments is found to be an important factor that determines crime hot spots with a statistical significance at $p < .01$ in 2010 and 2015. Road accessibility has a significantly positive impact on the likelihood of crime hot spots. In terms of the magnitude of the coefficient, road accessibility has the greatest impact on the potential for becoming hot spots of criminal activity.

The magnitude and statistical significance of spatial variables are proven to be important factors in identifying crime hot spots. The results suggest that effective spatial planning needs to be formulated with an aim to lower the chance of falling into hot spots for violent crimes.

Table 3-3. Spatial Probit Estimations for Violent Crime, 2005-2015

	2005		2010		2015	
	SAPM	SEPM	SAPM	SEPM	SAPM	SEPM
Intercept	39.0136**	20.7571	-38.6499***	-17.7136*	-18.8161**	-26.1956*
Pop	0.0626***	0.0475***	0.0846***	0.0471**	0.0539***	0.0527**
Foreign	0.1951**	0.1818*	0.2023**	0.1650**	0.0683*	0.0694**
Female	-0.5283	-0.2529	0.9088***	0.4415*	0.2749*	0.4253**
College	-0.2363***	-0.2632***	-0.2410**	-0.1361**	-0.0634*	-0.0883**
Emp	-0.1981***	-0.1207*	-0.1319	-0.0888	0.0605	0.1115
Own	-0.0327	-0.0414	-0.1122**	-0.0948**	-0.0463*	-0.0785**
Commer	-0.0740	0.0205	0.3249***	0.2233***	0.1321**	0.0948**
Road	4.0071***	4.2871***	1.3554***	1.7956***	1.3451**	1.4702***
ρ	0.6121***		0.7177***		0.6224***	
λ		0.5302***		0.7286***		0.3393***
N	116		116		145	

The SAPM model decomposes spatial autoregressive impact of the independent variables on the dependent variable into the direct, indirect or spillover, and total effects. <Table 3-4> presents the effects of each independent variable in determining violent crime hot spots⑦.

The magnitude of the indirect effects is greater than that of the direct effects for all the independent variables. This finding is reasonable, in that the impact of a change is likely to be smaller in the area that triggered the change. As the indirect effects are cumulated over all neighboring areas to become the violent crime hot spot, the impact on individual neighboring areas is likely to be larger than the direct effects that solely determine the hot spot for violent crime. It was found that the largest total effects are related to the proportion of female population and regional road accessibility with coefficients of around 0.14 and 0.45, respectively, in 2010.

⑦ Direct, indirect and total effects of independent variables of SAR model in chapter 2 are represented in <Appendix 5>.

All the demographic variables, including population, the proportion of foreign residents, and the ratio of females, have positive direct and total effects on the chances of being violent crime hot spots. The magnitude of the direct and total effects had diminished between 2010 and 2015. All the socio-economic variables had the negative direct and total effects on determining crime hot spots except for the employment rate in 2015. The effect of the employment rate on the chance to generate crime hot spots was positive in 2015. The spatial variables have positive direct and total effects on the dependent variable. The magnitude of both effects was reduced between 2010 and 2015, which is similar to the demographic variables.

The results imply that for an area to avoid the chance to become a violent crime hot spot, it is essential to manage both direct and indirect effects of a criminogenic environment. The direct and indirect effects of spatial variables are not negligible, which suggests that it is necessary to develop a spatial planning strategy, which is institutionalized to avoid becoming a hotbed of crime. The findings of the present study can be a useful guideline in formulating future crime prevention strategies for Seoul and the neighboring metropolitan areas.

Table 3-4. Direct, Indirect, and Total Effects of Independent Variables

	2005			2010			2015		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Pop	0.0021	0.0042	0.0062	0.0043	0.0106	0.0149	0.0048	0.0058	0.0106
Foreign	0.0036	0.0058	0.0094	0.0114	0.0242	0.0356	0.0041	0.0062	0.0102
Female	−0.0301	−0.0496	−0.0796	0.0408	0.0946	0.1354	0.0149	0.0222	0.0371
College	−0.0161	−0.0268	−0.0429	−0.0119	−0.0313	−0.0432	−0.0048	−0.0041	−0.0089
Emp	−0.0056	−0.0086	−0.0142	−0.0058	−0.0155	−0.0213	0.0031	0.0036	0.0067
Own	−0.0018	−0.0033	−0.0051	−0.0050	−0.0108	−0.0158	−0.0036	−0.0034	−0.0070
Commer	0.0015	0.0028	0.0043	0.0170	0.0408	0.0578	0.0097	0.0136	0.0233
Road	0.2809	0.4162	0.6971	0.1236	0.3217	0.4452	0.1326	0.1341	0.2667

3.5. Summary

This chapter investigated the effects of spatial factors that determine the violent crime hot spot. The spatial variation in crime hot spots was analyzed by applying two spatial probit regression models (SAPM and SEPM). The major findings of this paper are as follows.

First, the proportion of foreign residents and women proves to be a crucial factor that determines violent crime hot spots. It implies that where more foreigners and women reside, the level of violent crime incidence in those areas would not be lessened. The result highlights the necessity to reinforce the surveillance system and crime prevention environment in the regions where ratio of foreign residents and female population is high.

Second, the impact of the spatial variables that determine violent crime hot spots proves to be highly effective. All spatial variables were found to be in the range of the designated significance level, $p < .01$, in 2010 and 2015. The proportion of the hotel and restaurant establishments shows positive effects on determining violent crime hot spots. Furthermore, the higher the road accessibility of an area, the higher was the probability of becoming a violent crime hot spot.

Third, the magnitude of the indirect effects is greater than that of the direct effects for all the independent variables. This finding is an unexpected result, in that the impact of a change will most likely be smaller in the area that triggered the change. As indirect effects are cumulated over all neighboring areas to become a violent crime hot spot, the impact of individual neighboring areas is likely to be larger than the direct effect that solely determines the formation of crime hot spots.

This chapter concludes that since the crime prevention strategies should be based on the locality of the region, the results of the clustering analysis can provide basic information to incorporate idiosyncratic characteristics of local areas that are suitable for establishing crime prevention strategies.

Chapter 4. Conclusion

Crime occurs disproportionately, and regional disparities of crime opportunities are quite rampant over space across the world. Investigating idiosyncratic spatial characteristics on crime is important for criminological inquiries since crime is not randomly distributed over space, and different neighborhood circumstances can give rise to different crime motivations. Certain regional characteristics may be crime conducive that provides crime opportunities with low levels of vigilance. On the other hand, other areas with high levels of social and physical guardianship can enjoy a safe neighborhood environment that is free from crime occurrence.

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. This paper tries to find out the causal inference between violent crime and spatial features using diverse spatial econometric models and proposes alternative policies for desirable urban planning. Following the argument that crime is heavily influenced by built environment (Paulsen, 2011), this study found that spatial variables are highly correlated with violent crime incidence and violent crime hot spots.

Violent crime has everything to do with spaces. Thus, it is especially important to know how to control such statistical properties as spatial dependency and spatial heterogeneity when studying crimes. The present study has explored the impacts of spatial factors on violent crime incidence in Korea. To consider the spatial dependency of crime incidence, the present study adopts diverse spatial econometric models. Spatial variables adopted in the present study are the proportion of hotel and restaurant establishments and road accessibility of the region. The variables were proved to be quite effective to forecast the likelihood of violent crime incidence and violent crime hot spots. Moreover, this study presents the necessity of a suitable police deployment to deter the crime occurrence for Korea.

This chapter summarize major findings from the two empirical applications and propose planning implications, limitations and directions of future studies in the subsequent sections.

4.1. Summary of Findings

4.1.1. Chapter 2: Determinants on Violent Crime Incidence

This chapter investigated the determinants of violent crime incidence in Korea, focusing particularly on spatial effects on violent crime incidence. Since violent crime incidence is in general closely related to the spatial characteristics of a city, diverse spatial econometrics models (SAR, SEM, SAC, SDM, SDEM, SDAC, and SLX) were applied to incorporate the regional characteristics into the statistical models. The spatial variables adopted in this study the proportion of hotel and restaurant businesses and road accessibility of the region.

This chapter found that first, the proportion of hotel and restaurant business seems to be correlated with the violent crime incidence. As the higher proportion of hotel and restaurant business seems to induce crimes, it is recommended to reinforce the surveillance system and decentralize these facilities by public agency. Second, the road accessibility shows positive impacts on violent crime incidence. This is probably because the higher road accessibility leads to increased floating population where people become more likely to get exposed to crimes.

4.1.2. Chapter 3: Hot Spots in Violent Crime

This chapter investigated the determinants of the violent crime hot spot in Korea. Since crime hot spots are closely related to the spatial characteristics of a region, two spatial econometrics models (SAPM and SEPM) were applied to incorporate the regional characteristics into the statistical model. Spatial variables are the proportion of the hotel and restaurant businesses and the road

accessibility. The major findings of this chapter are as following.

First, the proportion of the hotel and restaurant businesses proves to be an important factor to identify violent crime hot spot. This result implies while more these businesses are located in violent crime hot spots, level of crime incidence of the areas would be increased. Second, the impact of road accessibility that identify the crime hot spot proves to be highly effective. Third, the magnitude of the indirect effects is greater than that of the direct effects for all the independent variables. This finding is notable in that the impact of a change will most likely be larger in the adjacent areas.

Next section presents planning implications and limitation of this thesis to incur some future directions of crime studies.

4.2. Implication, Limitations, and Future Study

Crime is one of the most widespread social problems of modern society. As crime is becoming worse and more challenging, demands for strategies and measures to reduce and deter crimes are ever increasing. Constructing diverse spatial variables and applying them to diverse spatial econometrics models, this dissertation undertook a comprehensive approach to the study of violent crime incidences and violent crime hot spots that recognizes the importance of space and built environment in crime studies. This study showed that neglecting these points neither guarantee high quality studies on crime nor catch detailed phenomena of crime incidence.

The present study focused on the spatial effects of violent crime incidence and suggested some important implications to urban planners and policymakers. First, land use restriction, if necessary, should be lifted for developing residential area to prevent the incidence of crime. If the government allows people to establish hotel and restaurant establishments without appropriate regulation, aggregate crime incidence can rise rapidly. To reduce crime incidence, therefore, commercial districts should be properly controlled by urban planning laws regulating maximum numbers of

entertainment establishments and accommodation businesses. Second, it is necessary to reinforce the surveillance system in regions with high road accessibility. Monitoring is a key factor that forestalls crime incidents, while developed road accessibility can render the criminals escape easier (Lee, 2011). Therefore, enhancing the efficiency of monitoring in regions with high road accessibility can be one effective strategy to prevent crime incidence. Furthermore, the Korean government should consider implementing Community Crime Watch (CCW) programs. These are designed to motivate neighborhood residents who witness suspicious behavior, disorder, and crime to report such activities to law enforcement and are intended to increase informal and formal crime control. Crime watch approaches have become the most prevalent means of citizen crime control and prevention at the neighborhood level. The presence of CCW programs is expected to increase neighborhood informal social control and social cohesion, which can result in elevated collective efficacy among residents (Louderback and Roy, 2018).

It is a common knowledge that the spatial variables adopted in the present study are fundamental components of spatial planning and that can be utilized to establish comprehensive urban master plans. An urban master plan determines fundamental frameworks including land use and location of facilities through planning processes. It is undeniable that urban master plans in Korea have rarely dealt with fundamental crime issues. Even though they save some sections for disaster prevention plans, those partial plans that mainly focus on natural disaster prevention strategies are not enough. Moreover, as the impacts of spatial planning on crime are expected to differ by regions, region-wide efforts, awareness, and participation should be encouraged to establish participatory and effective crime prevention measures. Further discussions must be followed to examine the effectiveness and conformity of each strategy.

One of the limitations of this study is the unavailability of rural data. Owing to the lack of spatial data on rural regions, subject areas were limited to urban areas. Moreover, it was not viable to

accommodate more diverse factors related to the occurrence of violent crimes in a spatial context. One of the independent variables not utilized is income inequality. There are many studies stating that income inequality leads to increased incidence of crime (Coccia, 2018; Hauner et al., 2012; Hooghe et al., 2011; Jang and Cho, 2019; Kim et al., 2014; Quimet, 2012). These limitations may restrict the interpretation and applicability of the results, although the findings remain relevant. More detailed data and information related to income inequality would yield a result that is more accurate and closer to reality.

In addition, due to the absence of time-series data on the spatial variables, the present study did not carry out a dynamic analysis to identify determinants of violent crime incidence. With the time-series data, future studies need to untangle the unique influence of the independent variable on the dependent variable. Further studies on this relationship that examines a longitudinal perspective are also needed, especially with reference to the factors that have not been adopted in the present study including urban planning facilities, zones, areas and districts. In addition, such studies will be based on microscopic data, rather than aggregated data, so that the relationship between more detailed microscopic characteristics of spaces and crimes can be identified.

As stated above, regional characteristics clearly affect the level of crime incidence. Further studies on the relationship between crime and urban planning policies are necessary for crime prevention and safer urban communities. In particular, interdisciplinary research between criminology and urban planning is essential to prevent crime in urban areas.

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Appendix 1. SAR, SEM, SAC Results of Total Crime, 2005−2015

	2005			2010			2015		
	SAR	SEM	SAC	SAR	SEM	SAC	SAR	SEM	SAC
Intercept	2.7457	10.9615	12.7830	−9.4135	31.1633	23.0614	−85.0854	−50.5167	−84.4191
Pop	3.1202***	10.9615	3.0344***	3.0354***	2.9640***	2.9698***	2.8891***	3.0487***	2.8942***
Foreign	2.1051	3.0674***	2.0833	1.5100**	1.3209*	1.3175*	1.9299***	1.8421***	1.9285***
Old	−2.8877***	2.0878	−2.8530***	−3.3742**	−2.7801**	−2.8271**	−2.2611***	−2.5132***	−2.2484***
Female	1.6828	−2.8747***	1.6216	3.5620	1.5361	1.6021	4.0862	3.5983	4.0572
Divorce	−6.0834	1.5965	−4.1593	−19.8867	−10.7932	−10.9554	6.5305	−5.3100	6.5274
S_house	1.7177**	−4.9777	1.5714*	2.3910***	2.1803**	2.2179**	0.8571	1.3405*	0.8621
College	−1.8054**	1.6265**	−1.8533**	−4.3166***	−3.6886***	−3.6976***	−1.0411	−1.6949*	−1.0288
Emp	−0.5847	−1.8456**	−0.5660	−1.0985	−0.5424	−0.5574	−0.5620	−1.3639	−0.5628
Tax	4.2428***	−0.5933	4.0276***	2.8838***	2.4946***	2.5051***	1.2265***	1.4356***	1.2275***
Immig	−1.4819***	4.1178***	−1.3947***	−2.1387**	−1.7489**	−1.7875**	−2.0297***	−2.4008***	−2.0371***
Commer	0.1826	−1.4377***	0.3017	1.1913	1.1286	1.1347	1.1850*	1.4302*	1.1739*
Road	−0.3672	0.2635	4.2795	14.6835	20.0742*	19.5802	9.0322	−1.0426	8.7840
	0.0409		−0.0505	0.0460		0.0527	−0.5438***		−0.5403**
		0.2099	0.3147		0.6451**	0.6514**		−0.0747	−0.0274
LM(lag)	0.07		0.03	0.05		0.04	7.47***		11.03***
LM(error)		0.21	0.2		5.17**	5.62**		0.01	0
AIC	1098	1098	1100	1167	1164	1166	1402	1409	1404
SBC	1139	1139	1144	1209	1206	1210	1447	1454	1452
N		116			116			145	

* p<.1, ** p<.05, *** p<.01

Appendix 2. SAR, SEM, SAC Results of Heinous Crime, 2005-2015

	2005			2010			2015		
	SAR	SEM	SAC	SAR	SEM	SAC	SAR	SEM	SAC
Intercept	-144.036	-143.9023	-143.9627	-17.7384	-109.7088	-57.8407	-877.6456 *	-773.9372	-906.7511 *
Pop	3.1068***	2.9858***	3.1059***	2.8040***	2.7326***	2.8631***	3.2122***	3.4622***	3.1211***
Foreign	3.0234*	2.9150*	3.0216*	3.1111***	2.7111**	2.6684**	1.9745*	1.9026*	2.0054*
Old	-5.6939***	-5.5261***	-5.6926***	-6.9097***	-6.0167***	-6.4020***	-3.8785*	-3.9207*	-4.1525*
Female	3.7474	3.8221	3.7446	6.5867	6.1741	5.1449	13.9439	12.5512	14.9180
Divorce	-12.0127	-8.0335	-11.9804	-33.8876	-16.6094	-23.8527	34.5673	22.7268	33.6070
S_house	5.0679***	4.8396***	5.0660***	4.5419***	4.2916***	4.8040***	3.7316**	4.1990**	3.6918**
College	-3.5152***	-3.5863***	-3.5167***	-7.1322***	-6.1020***	-6.3589***	-0.0875	-0.5658	-0.3066
Emp	-0.5238	-0.4253	-0.5241	-3.0356*	-1.3793	-1.9472	1.4675	0.7036	1.3962
Tax	0.6732	0.3014	0.6704	1.6122*	0.9486	1.2495	0.1397	0.3696	0.1595
Immig	-0.8041	-0.5905	-0.8026	-3.5505***	-2.6106**	-3.2038**	-1.9791	-2.5109	-1.8217
Commer	1.1356	1.3209*	1.1378	2.8595**	2.7023**	2.6613**	2.0612	2.0835	2.2758
Road	50.4788***	58.8544***	50.5493***	107.3556***	118.2780***	109.1489***	168.6550***	152.1717***	172.7217***
	0.1448		0.1441	0.2997**		0.2961	-0.1739***		-0.2105**
		0.3783	0.0045		0.7091***	0.6439***		-0.1905	0.1942
LM(lag)	1.7		1.24	4.24**		3.06*	1.5***		1.28***
LM(error)		1.23	0		9.12***	6.48**		0.09	0.11
AIC	1156	1156	1158	1262	1261	1260	1684	1685	1686
SBC	1197	1198	1202	1304	1333	1333	1729	1730	1734
N	116			116			145		

* p<.1, ** p<.05, *** p<.01

Appendix 3. SDM, SDEM, SDAC, SLX Results of Total Crime, 2005−2015

	2005				2010				2015			
	SDM	SDEM	SDAC	SLX	SDM	SDEM	SDAC	SLX	SDM	SDEM	SDAC	SLX
Intercept	-4428.55**	-3739.97***	-4248.53***	-3051.44*	-5543.30**	-3679.09	-4524.22*	-4368.07*	662.45	3509.40	3257.87	658.66
Pop	2.382***	2.348***	2.310***	2.400***	2.807***	2.777***	2.822***	2.693***	2.445***	2.446***	2.419***	2.414***
Foreign	1.354	1.548	1.747	0.777	2.128***	1.854***	1.970***	1.923***	2.137***	1.903***	1.943***	2.148***
Old	-3.475***	-3.702***	-3.760***	-3.177***	-4.206***	-3.472***	-3.668***	-3.760***	-2.526***	-2.778***	-2.607***	-2.871***
Female	4.577	4.147	4.647*	2.965	7.860**	5.117	6.046	5.874	3.207	3.866	3.374	3.627
Divorce	14.401	10.914	10.917	16.529*	-11.325	-4.460	-6.332	-7.013	-0.287	2.491	1.734	0.024
S_house	0.582	0.780	0.648	0.666	1.221	1.261	1.263	1.102	0.303	0.524	0.436	0.377
College	-1.106	-1.513*	-1.519*	-1.090	-4.252***	-3.291***	-3.506***	-3.871***	-1.082	-1.286	-1.092	-1.536*
Emp	0.197	0.016	-0.036	0.232	-0.343	-0.219	-0.203	-0.440	-0.879	-0.295	-0.464	-0.822
Tax	2.211**	2.314***	2.298***	2.043**	2.541***	2.241***	2.354***	2.306***	1.159***	1.089***	1.090***	1.158***
Immig	-1.567***	-1.441***	-1.494***	-1.410***	-2.553***	-2.363***	-2.467***	-2.339***	-2.391***	-2.242***	-2.333***	-2.214***
Commer	0.111	0.385	0.373	0.214	1.237*	0.593	0.697	1.155	1.424***	1.369**	1.321**	1.693***
Road	34.392***	38.964***	39.164***	36.964***	28.207**	26.778**	25.327**	31.984**	24.656***	29.672***	29.173***	27.400***
W_pop	8.266***	2.487	3.692	4.572*	10.780***	6.280**	8.362**	6.654**	11.854***	0.775	5.675	2.336
W_foreign	-15.732	-7.267	-0.802	-34.849	20.509**	17.374**	20.698**	14.222*	7.785	1.013	5.660	-1.920
W_old	6.888	8.357	5.566	15.051	4.135	23.797**	18.274	11.164	18.563**	32.667***	30.668***	21.050**
W_female	61.571	65.425**	78.164**	26.536	128.425***	83.735**	103.942**	98.918**	7.013	-54.193	-41.795	-4.619
W_divorce	14.887	-53.640	-77.920	80.627	-365.067***	-267.593**	-298.523**	-321.879**	-60.573	59.355	18.0075	-23.304
W_s_house	-4.564	-12.029*	-12.530*	-3.684	-11.764	-24.600***	-22.318***	-14.007	-17.463**	-26.941***	-26.396***	-19.370**
W_college	6.213	-3.091	-4.995	12.099	-26.331**	-12.634*	-17.102*	-19.217**	6.801	14.843**	12.880**	7.773
W_emp	30.398***	21.572**	21.779**	31.256***	9.116	11.766	10.310	12.858	-11.436	-14.649*	-17.898**	-2.879
W_tax	6.027	-2.174	1.7974	-3.008	23.328***	21.523***	24.711***	16.664**	7.296**	1.065	4.138	1.396
W_immig	-11.997*	-10.285*	-11.252**	-9.415	-29.415***	-28.147***	-30.820***	-23.833**	-6.468	-2.021	-4.712	-0.086
W_commer	-19.209**	-15.739*	-16.631*	-18.771*	-3.536	-6.308	-4.638	-7.180	-18.078**	-19.195***	-20.166***	-18.171**
W_road	-87.866	-15.536	-38.634	-39.335	-149.940	-164.202	-179.862	-122.122	-205.009**	-51.116	-113.467	-88.230
ρ	-1.417**		-0.457		-0.981*		-0.472		-2.700***		-1.304*	
λ		-3.112***	-2.902***			-2.415***	-2.144**			-3.782***	-3.214***	
LM(lag)	4.44**		0.59		2.49		0.61		9.4***		2.51	
LM(error)		8.26***	5.4**			5.16**	3.63*			12.07***	5.66**	
AIC	1084	1075	1077	1087	1143	1138	1139	1144	1387	1380	1379	1399
SBC	1158	1150	1154	1159	1217	1212	1216	1215	1467	1460	1462	1476
N	116				116				145			

* p<.1, ** p<.05, *** p<.01

Appendix 4. SDM, SDEM, SDAC, SLX Results of Heinous Crime, 2005−2015

	2005				2010				2015			
	SDM	SDEM	SDAC	SLX	SDM	SDEM	SDAC	SLX	SDM	SDEM	SDAC	SLX
Intercept	-7653.73**	-477.68***	-7761.18***	-4277.40*	2050.62	6799.99	6840.70	2053.53	7369.37	11059.00*	8939.12	7408.03
Pop	2.565***	2.684***	2.501***	2.689***	2.661***	2.921***	2.969***	2.664***	2.155***	2.163***	2.023***	2.222***
Foreign	3.265*	2.517	3.445*	2.128	3.073***	2.851***	2.603**	3.127***	1.931**	1.879**	1.786*	2.095**
Old	-6.444***	-6.003***	-6.492***	-5.766***	-6.035***	-5.693***	-6.018***	-6.009***	-3.674*	-4.379**	-3.940**	-4.645**
Female	9.048**	6.950*	9.356**	5.524	4.304	1.698	1.926	4.365	9.567	12.733*	11.840*	12.017
Divorce	1.183	-0.190	-0.769	3.823	-35.348	-35.886*	-35.054	-35.703	28.449	25.699	30.365	17.847
S_house	3.746***	4.274***	3.871***	3.923***	3.418**	3.894**	4.409***	3.355**	3.495**	3.683**	3.714**	3.660**
College	-3.331***	-3.553***	-3.577***	-3.453***	-7.116***	-6.446***	-6.411***	-7.125***	1.090	0.520	1.324	-0.400
Emp	0.177	-0.013	-0.117	0.081	-3.334*	-3.210*	-2.928*	-3.379*	-0.379	1.202	0.839	-0.168
Tax	-0.135	0.006	-0.100	-0.204	1.453	1.606*	1.531*	1.481*	-0.595	-0.430	-0.580	-0.241
Immig	-0.994*	-0.744	-0.918	-0.750	-3.806***	-4.205***	-4.173***	-3.832***	-3.317**	-2.347*	-2.641*	-2.530
Commer	0.917	0.901	0.887	1.159	2.068*	0.786	0.730	2.044*	1.771	1.833	1.543	2.952*
Road	64.057***	68.871***	69.954***	67.184***	113.852***	98.086***	97.023***	113.338***	228.837***	233.371***	238.614***	224.978***
W_pop	2.424***	-4.378	-2.480	-0.743	1.987	1.740	0.598	2.283	19.143**	0.863	7.525	8.291
W_foreign	25.856	11.956	41.119	-5.882	14.554**	18.766**	12.442	16.242	4.146	-6.689	-0.058	-7.849
W_old	-26.149	-9.920	-26.580	-6.789	16.987	51.413***	52.679***	17.182	39.957*	58.055***	50.461**	37.8482
W_female	128.688**	80.297**	144.623***	60.839	30.991	-50.026	-60.903	33.018	-151.230	-211.347**	-182.105*	37.848
W_divorce	-82.611	-50.522	-145.645	5.735	-539.147**	-487.361**	-482.130**	-538.300**	343.897	440.058***	502.303***	-132.401
W_s_house	-2.416	-9.609	-8.864	-6.182	-31.481**	-57.380***	-54.755***	-32.522**	-19.120	-46.809***	-38.056**	134.679
W_college	8.700	8.290	0.579	15.915	-22.496	-6.365	-2.669	-23.048	-13.522*	-16.978**	-18.615**	-31.184
W_work	35.702**	24.980*	29.042**	30.526*	-11.501	-25.907*	-19.415	-13.075	20.322	23.549	26.163*	-13.170
W_tax	3.609	-6.766	-0.379	0.640	16.572	28.794**	24.924**	17.725	-5.746	-19.559	-7.737	3.890
W_immig	-12.956	-6.434	-9.148	-11.260	-15.964	-22.357	-20.765	-16.619	-29.188*	-20.931**	-30.133***	-11.878
W_commer	-21.902*	-17.095	-16.589	-24.193*	-26.702	-25.173	-27.881*	-25.859	-50.143***	-40.059**	-49.705***	-13.249*
W_road	-83.826	-66.278	-81.885	-96.794	31.600	-5.846	-39.781	38.118	472.090**	326.392	467.063**	-35.313
ρ	-1.794***		-1.235*		0.1350		0.555*		-2.752***		-1.509**	
λ		-3.294***	-2.990***			-2.175**	-2.668***			-3.958***	-3.430***	
LM(lag)	6.60**		3.29*		0.09		2.87*		11.89***	14.70***	4.07**	
LM(error)		8.77***	6.80***			2.13	5.65**				7.18***	
AIC	1147	1141	1139	1154	1259	1256	1256	1257	1659	1651	1648	1674
SBC	1222	1215	1216	1226		1302	1304	1302	1740	1732	1731	1751
N	116				116				145			

* p<.1, ** p<.05, *** p<.01

Appendix 5. Direct, Indirect and Total Effects of Independent Variables

	2005			2010			2015		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Pop	0.4148	0.3005	0.7154	0.3683	0.2153	0.5836	0.3365	0.0260	0.3624
Foreign	0.3239	0.2280	0.5519	0.2542	0.1492	0.4034	0.3082	0.0218	0.3300
Old	−0.6917	−0.4963	−1.1881	−0.4510	−0.2767	−0.7278	−0.5169	−0.0392	−0.5561
Female	0.5897	0.3803	0.9700	0.6896	0.4090	1.0986	1.0885	0.0732	1.1616
Divorce	−0.5417	−0.5057	−1.0474	−0.3738	−0.4597	−0.8335	0.7145	−0.0445	0.6700
S_house	0.2366	0.1758	0.4124	0.2643	0.1668	0.4312	0.1663	0.0159	0.1822
College	−0.5356	−0.3821	−0.9177	−0.6120	−0.3630	−0.9749	−0.3457	−0.0294	−0.3751
Emp	−0.3609	−0.2702	−0.6311	−0.3133	−0.1999	−0.5132	−0.1121	−0.0152	−0.1273
Tax	0.0541	0.0530	0.1071	0.1199	0.0787	0.1986	0.0546	0.0057	0.0603
Immig	−0.3225	−0.2420	−0.5645	−0.3172	−0.1973	−0.5145	−0.2166	−0.0192	−0.2358
Commer	0.1468	0.0999	0.2467	0.2878	0.1643	0.4521	0.3194	0.0245	0.3439
Road	7.9224	5.3588	13.2812	7.3975	4.0353	11.4328	4.7489	0.2535	5.0024

국문초록

강력범죄 발생 및 강력범죄 핫스팟 형성에 영향을 미치는 지역 특성에 대한 연구

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본 연구의 목적은 공간선형모형과 공간이산선택모형을 활용하여 강력범죄와 지역의 공간적 특성 간의 인과관계를 규명하고 대한민국의 도시환경을 위한 대안을 제안하는 것이다. 본 연구에서 채택한 공간 계획적 변인은 지역의 호텔 및 외식업의 비율과 도로접근성이다. 이 두 변수는 산업구조와 인구유입을 반영하는 중요한 요인이다. 본 논문은 두 개의 에세이로 구성되어 있다.

첫 번째 실증분석에서는 인구통계학적, 사회경제적, 공간선형모형을 활용하여 공간적 요인이 강력범죄에 미치는 영향을 분석하였다. 그 결과 호텔과 외식업의 증가가 범죄 발생률과 정(+)의 상관관계가 있는 것으로 나타났다. 또한 도로 접근성의 향상은 범죄에 긍정적인 영향을 미치는 것으로 드러났다.

두 번째 실증분석은 공간이산선택모형을 이용하여 공간 계획적 변인이 강력 범죄 핫스팟 형성에 미치는 영향을 분석하였다. 그 결과 강력범죄 핫스팟 형성에 있어서 공간 변인의 영향이 매우 높은 것으로 나타났다. 호텔과 음식점의 비율은 강력범죄 핫스팟 결정에 긍정적인 영향을 미치는 것으로 나타났으며 도로접근성이 높은 지역일수록 강력범죄 핫스팟이 될 가능성이 높은 것으로 밝혀졌다.

지역적 특성은 범죄 발생률에 분명히 영향을 미친다. 이를 바탕으로 본 논문은 도시계획가와 정책입안자들에게 몇 가지 시사점을 제시하였다. 한편 범죄 예방과 안전한 도시 공동체를 위해서는 범죄와 도시 계획 정책의 관계에 대한 추가 연구가 필요하다. 특히 도시지역 범죄예방을 위해서는 범죄학과 도시계획의 학제간 연구가 필수적이다.

Keyword : 범죄발생, 범죄핫스팟, 공간선형모형, 공간이산모형, 접근성, 지역계획

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