Spatial and Temporal Analyses of Crime Rates and Neighborhood Characteristics

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犯罪率と地域特性の時空間分析

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Abstract: 犯罪の空間的分析や数多く行われているもの、それらに時間的要素を加えた分析は少ない。今研究では、アメリカ国勢調査の小地域集計単位での犯罪集計を用いて、シアトル市内における 1960 年から 2005 年までの犯罪の変化を分析した。統計モデルとして、成長曲線モデルを採用し、各地域における犯罪率の変化の軌跡のばらつきを分析した。

Key words: 犯罪：縦断的分析；地域特性；成長曲線モデル.

1 Introduction

Spatial and temporal analyses of crime have been classic topics in criminology. For example, several of the first empirical studies in criminology by European scholars, such as Guerry, Quetelet, and Durkheim, involved analyses of the spatial distribution of crime in France (Beirne 1993). Furthermore, in the United States, Shaw and McKay (1942) conducted a seminal study of juvenile delinquency in Chicago that illustrated the spatial concentration of juvenile delinquency in the inner city over time. Such theories as social disorganization theory and routine activities theory were also proposed and tested in order to provide theoretical frameworks in explaining the spatial distribution of crime. (Cohen and Felson 1979; Miethe and Meier 1990; Shaw and McKay 1942).

Despite the popularity of studying crime at the neighborhood level, reviews of existing literature have identified several limitations, most notably a failure to incorporate spatial and temporal dynamics of crime at the neighborhood level (Kubrin and Weitzer 2003). That is, although there are many studies that have examined the relationship between neighborhood characteristics and crime using cross-sectional data, the temporal aspects of crime at the neighborhood level have received limited attention (Bursik and Grasmick 1992; Kubrin and Herting 2003). Furthermore, some existing longitudinal studies of crime were conducted at a highly aggregated macro level (e.g., states, counties, and cities), although it is recognized that neighborhood characteristics are likely to vary considerably within cities.

Official crime statistics in the United States (e.g., Uniform Crime Reports) indicate the country experienced a rapid increase in violent crime between 1960 and the late 1980s, followed by a decrease. Many cities followed similar patterns of crime rate increases and decreases. What is less known, however, is whether neighborhoods *within* cities followed a similar rapid increase and decrease in crime over time. Despite city-level statistics showing crime rate increases, many neighborhoods might have remained safe.

In order to address this limitation in the existing literature, this paper analyzes the nature of crime rate changes at the neighborhood level using longitudinal data. In particular, growth curve modeling is proposed as an analytical strategy to examine group level trend and individual variability in crime

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trajectories over time.

2 Research Questions

In order to systematically conduct quantitative analysis, the following research questions were identified:

1) Is there evidence of a systematic trend and individual variability in trajectories of crime over time?
2) Is there any association between the initial level of crime and rate of change over time?
3) What are the characteristics of the spatial distribution of crime trajectories?

3 Data

Crime data at the census tract level in Seattle, WA, in 1960, 1970, and 1980, were obtained through the Inter-university Consortium for Political and Social Research (ICPSR: study number 9741). Additionally, crime data in 1990, 2000, and 2005 were directly obtained by contacting the Seattle Police Department. Crime variables followed the definitions in the Uniform Crime Reports, collected by the Federal Bureau of Investigation, and included homicide, robbery, burglary, and auto theft. The crime variables were calculated as rates per 1,000 people per census tract.

4 Statistical Model: Growth Curve Model

A growth curve model is suitable for answering the research questions posed in Section 2 because it analyzes a trajectory at the group level along with individual variability in growth patterns (Kubrin and Herting 2003; Singer and Willett 2003).

The basic idea behind a growth curve model is to estimate regression lines (or curves) for each individual observation (Figure 1). It is quite possible that such regression lines vary considerably in their functional forms across individuals. Some may show an increase, while others show a static pattern over time. The varying regression lines at the individual level are then smoothed to produce summary measures (e.g., mean and variance) that characterize the average trend for individuals as a whole. It is this unobserved curve that is believed to underlie and to have given rise to the observed data. While various regression lines based on observed data reflect individual level patterns, the unobserved curve represents the group level trend.

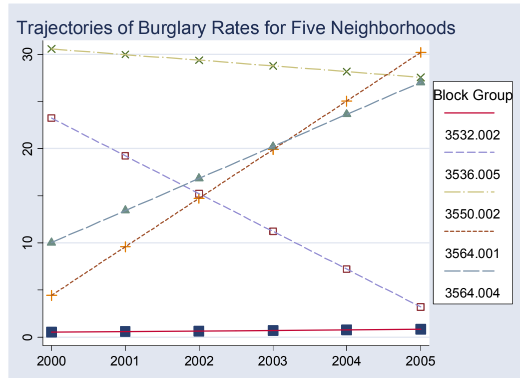

Fig 1. An Illustration of Linear Trajectories of Crime

Formally, a growth curve model can be expressed as a multilevel model where there are two levels (Singer and Willett 2003). The first level equation that assesses changes within neighborhood is

$$y_{it} = \alpha_i + \beta_i (Time)_{it} + \varepsilon_{it}$$

where y_{it} is a crime rate for neighborhood i at time t, and α_i and β_i are an intercept and slope that characterize the trajectory pattern for each neighborhood. The subscript i of α and β indicates possible variation across individual neighborhoods in trajectory patterns. In order to capture this variation across individual neighborhoods, the second level equations that express the intercept and slope are formed as

$$\alpha_i = \mu_\alpha + \xi_{\alpha_i} \text{ and } \beta_i = \mu_\beta + \xi_{\beta_i}$$

The ξ indicates the extent of deviation from the mean intercept and slope for each neighborhood in the trajectory patterns. Substituting α_i and β_i in the level-1 equation gives the combined model.

$$y_{it} = \{\mu_\alpha + (Time)_{it}\,\mu_\beta\} + [\xi_{\alpha_i} + \xi_{\beta_i}(Time)_{it} + \varepsilon_{it}]$$

The terms in the first bracket reflect a fixed component, while the terms in the second bracket reflect a random component. That is, while the fixed component captures the overall trajectory pattern across neighborhoods, the random component reflects individual variability in trajectory patterns.

Using a growth curve model for the analysis of change is advantageous for several reasons (Kubrin and Herting 2003; Singer and Willett 2003). First, a growth curve model provides summary measures (e.g., mean and variance) to characterize an underlying trajectory that has given rise to a large set of observations. Furthermore, by including additional terms, such as time-squared, in the above equation, various functional forms can also be incorporated in order to assess non-linear rate of change (acceleration or deceleration). Predictors can also be included to explain the variability in the initial level and rate of change over time.

5 Results

In order to answer the first research question about the overall functional form of crime rate changes at the neighborhood level, unconditional growth curve models with only crime and time variables were specified. The parameter estimates of the non-linear growth curve model with quadratic terms are presented in Table 1. As expected, the overall trend of crime rate changes for homicide, robbery, and burglary between 1960 and 2005 were characterized by a non-linear trend with an initial increase and subsequent non-linear decrease. For example, the average trajectory of homicide in this time period was characterized as:

$$Homicide_t = 0.069 + 0.048 Time_t - 0.013 Time_t^2$$

By substituting the value of time with 0 for 1960, 1 for 1970 and so forth, a predicted mean level of crime at each time point can be obtained.

Table 1. Parameter Estimates of Growth Curve Models

	Homicide	Robbery	Burglary	Auto Theft
Intercept	0.069	1.089	10.831	5.015
	(0.010)	(0.201)	(0.701)	(0.330)
Time	0.048	3.853	15.139	1.815
	(0.011)	(0.652)	(0.936)	(0.381)
$Time^2$	-0.013	-0.789	-3.4842	0.203
	(0.003)	(0.142)	(0.223)	(0.084)

Note: standard errors are reported in parentheses.

In contrast to homicide, robbery, and burglary, the non-linear trend of auto theft was characterized as an upward trend (acceleration), which captured an increase in the number of crime targets (i.e., cars) in this time period due to the expansion of motorization.

It is important to note, however, that the growth curve models indicated considerable individual variability in both the initial level of crime and rate of change across neighborhoods, as indicated by statistically significant random effects associated with the estimates of each growth curve parameter (the diagonal elements in Table 2). That is, while the overall group-trend may be characterized by the parameter estimates presented in Table 1, trajectory forms varied considerably across neighborhoods. For example, although the estimated mean level of homicide in 1960 was 0.069, the levels of homicide varied significantly for each neighborhood (variance = 0.02, $p<.01$). More interestingly, the rate of change varied for each neighborhood. For example, the estimated mean rate of linear increase in homicide was 0.048, although the statistically significant variance of the linear term indicated the rate of linear change varied considerably for each neighborhood (variance = 0.02, $p<.01$).

Characteristics of individual trajectories of crime can also be analyzed by examining the covariance estimates among growth curve parameters (the off-diagonal elements in Table 2). The covariance estimate of the intercept (i.e., initial level) and linear term was positive for the homicide trajectory, indicating that a larger value of the intercept was associated with a larger value of the linear term (bigger slope = faster increase). That is, neighborhoods with higher initial levels of homicide in 1960 were predicted to experience a faster linear increase in homicide than neighborhoods with lower initial levels of homicide. The covariance estimate of the intercept and quadratic term can also be interpreted in a similar manner. A negative covariance for the intercept and quadratic term for the homicide trajectory indicated that a larger value of the intercept was associated with a smaller value of the quadratic term. Thus, the negative covariance between the intercept and the quadratic term for homicide indicated that neighborhoods with a higher initial level of homicide in 1960 experienced a steeper downward change at later time periods.

Table 2. Variance-Covariance Matrix of Random Effects of Growth Curve Models

		Homicide			Robbery			Burglary			Auto Theft		
		Int.	Linear	Quad.	Int.	Linear	Quad.	Int.	Linear	Quad.	Int.	Linear	Quad.
Homicide	Intercept	0.02											
	Linear	0.02	0.02										
	Quad.	0.00	-0.01	0.00									
Robbery	Intercept	0.33	0.33	-0.08	6.59								
	Linear	1.43	1.50	-0.38	30.64	128.76							
	Quad.	-0.32	-0.33	0.08	-6.67	-28.75	6.11						
Burglary	Intercept	1.16	1.12	-0.28	24.95	103.56	-22.79	69.44					
	Linear	1.52	1.83	-0.45	27.02	127.69	-28.42	104.22	172.60				
	Quad.	-0.36	-0.43	0.11	-6.62	-30.74	6.83	-25.75	-50.31	10.11			
Auto Theft	Intercept	0.51	0.47	-0.12	9.76	43.10	-9.56	48.52	48.18	-11.81	8.38		
	Linear	0.53	0.67	-0.16	11.75	51.33	-11.31	32.92	79.98	-18.34	-3.00	20.88	
	Quad.	-0.10	-0.12	0.03	-2.50	-9.95	2.17	-6.04	-13.30	3.09	0.75	-10.11	1.13

The covariance estimates for other crime types can also be interpreted in a similar manner.

Finally, the predicted parameter estimates of the growth curve models can also be plotted on maps to visually examine the results As an illustration, Figure 2 shows the spatial distribution of growth curve parameter estimates in Seattle for homicide (maps for other crime types are available upon request). As for the initial level of homicide and linear rate of change, higher values were concentrated around downtown areas; that is, neighborhoods in these areas experienced a faster linear increase in homicide than other areas.

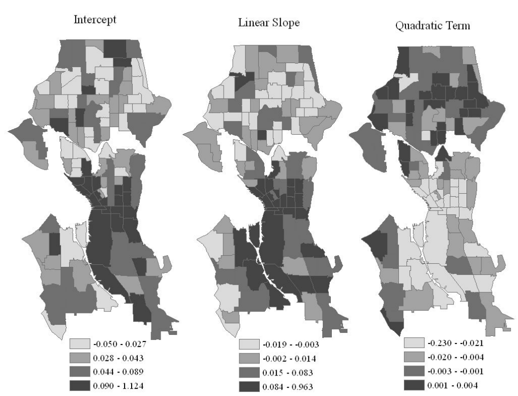

Fig 2. Spatial Distribution of Growth Curve Parameter Estimates for Homicide

6 Summary

While spatial analyses of crime have been popular topics in criminology, previous studies paid little attention to temporal changes in the level of crime. Using longitudinal data of crime and neighborhoods between 1960 and 2005, this study examined the nature of change in the level of crime at the neighborhood level. As a statistical model, the growth curve models were used in order to analyze group level trend and individual variability simultaneously.

Overall, the results of the growth curve models indicated that there was considerable variability in both initial level of crime and rate of change for all crime types. Furthermore, the parameter estimates of growth curve models were spatially clustered, indicating that spatial dependency existed not only for the initial level of crime, but also for the rate of change. The results also indicated that neighborhoods with a higher initial level of crimes experienced a faster linear increase in the level of crime over time than other neighborhoods. Neighborhoods located on the outskirts of Seattle, on the other hand, experienced less rapid change in the level of crime than other areas in the city. Future research should incorporate neighborhood characteristics as predictors to explain the individual variability in trajectory forms.

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