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STATISTICAL TEST WITH SPATIAL ECONOMETRIC MODEL ON BROKEN-WINDOWS HYPOTHESIS FOR TAIWAN

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Abstract. *During the period from 2005 to 2015, there were significant decreases in serious crimes throughout Taiwan area. Bratton's broken-windows hypothesis indicated that following the increase in arrest for crime, the increased police vigilance would change the behavior of individuals. The question of whether economic conditions or deterrence policies are more effective tools of crime control has become an important political issue in this country. How much is the space spillover effect of economic conditions, deterrence policies, and spatial lag criminal cases on serious crime? This research finds the remarkable decline in serious criminal activity is attributable to improved economic conditions and deterrence measures. Both economic and deterrence variables are important in explaining the decline in crime; however, the contribution of deterrence measures is larger than those of economic variables.*
Keywords: Spatial econometric model, Broken-windows hypothesis, Deterrence policies, Spillover effect, Criminal activity

1. **Introduction.** During the period from 2005 to 2015, there were significant decreases in serious crimes throughout Taiwan area. Criminal rates fell by about 27.53 percent during this period from 2005 to 2015 in Taipei city, and violent crime rates fell by about 66.75 percent. Many other cities fared even better than capital trends in crime reduction. The most influential article proposed by [1] suggested that aiming at minor disorder could help reduce more serious crimes. The "broken windows" theory generated a revolution in policing and law enforcement practically. The most three populous cities – New York, Chicago, and Los Angeles – have all adopted some aspects of Wilson and Keeling's broken-windows theory with aggressive enforcement of misdemeanor laws. There are many social problems arising from the inefficiency of housing market. One potential impact of increased housing market inefficiency in a city is vacancy which was proved to lead to high crimes empirically. The question of whether social and economic conditions or deterrence policies are more effective tools of crime reduction has become an important issue of resource distribution and political decision in Taiwan area.

The purposes of this paper are threefold. Firstly, it investigates the effects of economic conditions and social deterrence measures on four serious crimes in Taiwan area in 2015. The spatial Durbin model to comprise these variables jointly in a crime supply equation allows us to estimate the influence extent of economic and social deterrence measures in a distinct structure. Secondly, in proof of the validity of broken-windows hypothesis, the cross section data from Survey Research Data Archive which was founded in 2015 in Taiwan is applied to constructing the crime supply equation. Thirdly, the broken windows theory has led to initiatives that sought to reduce crimes by sealing or removing vacant buildings [2,3]. In order to better quantify the relationship between crimes and vacancy empirically, it examines the connection of crimes and vacant properties. Are increasing levels of vacancy associated with increased risk of crime in Taiwan? The researches of [4-9]

concluded a significant effect of sanctions on criminal cases. Although varied in both of variables and econometric methods, all of the researches find that variables associated with expected deterrence are more significantly related to crime than investigated in previous researches. For more results on the topics of crime influenced by joblessness, wages, public finance, and demographics, this research refers readers to [10-13] and the references have demonstrated a strong effect of economic conditions on crime.

The paper is structured as follows. In Section 2, by reviewing the studies on crime causal relationship and dependency of crime have been aggregated. Section 3 presents some theoretical background and introduces the statistical model and the data used in this empirical application. In Section 4, the empirical findings are presented and interpreted. And finally, Section 5 concludes the analysis.

2. **Economic Condition and Sanction on Crime.** Evidence of [14-17] shows that crime, both property and violence, has been declining in the United States since the beginning of 1990. The data also suggest that despite a general downward trend, the variation in crime rates across regions is considerable. A growing academic literature has been studying the causal factors explaining changes in crime rates. Most of these work attempts to determine whether the decline in crime can be attributed to more effective deterrence policies or to better economic conditions that facilitate access to legitimate labor market opportunities. It concludes that the relationships between crime and arrests and between crime and legitimate labor market opportunities are very heterogeneous across cities and types of crimes. Even though arrests seem to lower crime, they only have an effective deterrent impact in some cities. Lower unemployment and higher real minimum wages contribute to decreased crime rates, but their impact is not significant for all types of crime and for all cities. Crime leads to fear and anxiety in society as well as disturbs social order and harmony. Therefore, authorities aim at eliminating crime which adversely affects society, both physically and economically. [18-21] show that economic capacity and education affect crime negatively while factors such as inflation rate, employment capacity and urban population have positive effects by spatial panel models. Most of this study attempts to determine whether the decline in crime in Taiwan can be attributed to more effective deterrence policies or to better economic conditions that facilitate access to legitimate labor market opportunities. The conclusions of this research may provide guidance concerning the kinds of policies that are most effective in controlling crime.

3. **Crimes and Spatial Econometric Model.** In the last decade, there were significant decreases in serious crime throughout Taiwan. From 2005 to 2015, criminal rate fell by about 46.48 percent, larceny rate fell by about 79.83 percent, violence rate fell by about 86.39 percent nationally, nonetheless disposal income per household rose by about 7.86 percent nationally (Figures 1 to 4). The question of whether economic conditions or deterrence policies are more effective tools of crime control has become an important political issue in this country. How much is the space spillover effect of economic conditions, deterrence policies, and spatial lag criminal cases on serious crime?

Spatial econometrics is a subfield of econometrics that deals with spatial interaction and spatial structure in regression models for cross-sectional and panel data [21-23] and it provides the estimates of space spillover effects for the decision on space related policy. A non-spatial model, ordinary least square (OLS), is expressed as:

$$y = \alpha + X\beta + u, \tag{1}$$

with y as a vector of criminal case, X as a matrix of explanatory variables, α and β as parameters, and u as a vector of random disturbance terms. In the standard linear regression model, spatial dependence can be incorporated in three distinct ways: as an additional regressor in the form of a spatially lagged dependent variable (spatial lag model;

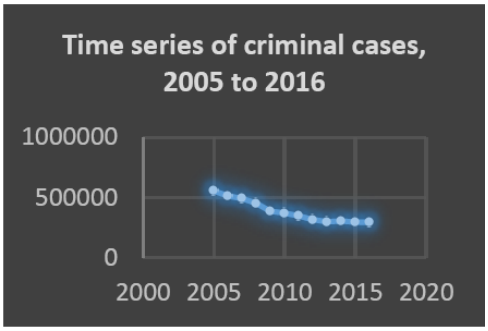

FIGURE 1. Time series of criminal cases

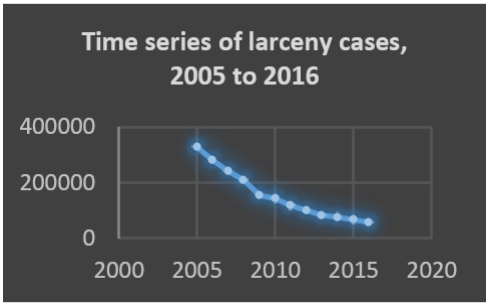

FIGURE 2. Time series of larceny cases

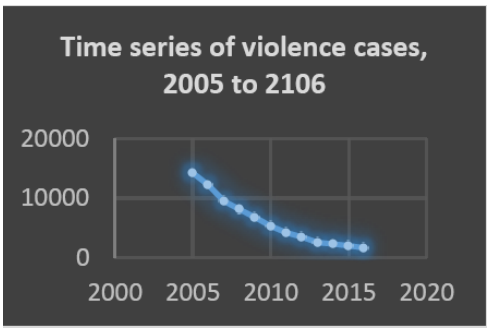

FIGURE 3. Time series of violence cases

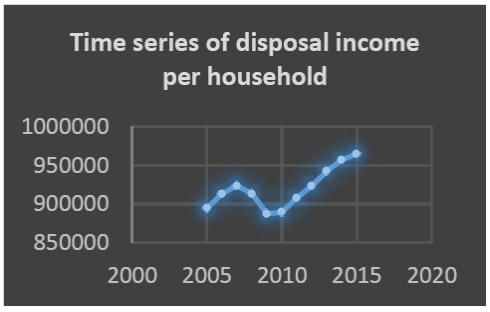

FIGURE 4. Time series of disposal income per household

SLM), additional regressors in the form of spatially lagged explanatory variables (spatial durbin model; SDM), and in the error structure (spatial error model; SEM). Formally, a spatial lag model of serious criminal case is expressed as:

$$y = \alpha + \rho W y + X\beta + u, \tag{2}$$

where ρ is a spatial autoregressive coefficient, and Wy is a vector of spatial lag term of criminal case. A spatial error model which treats spatial correlation primarily as a

nuisance is expressed as:

$$y = \alpha + X\beta + \lambda W\xi + u, \tag{3}$$

where ξ is a vector of spatial component of error term, and λ is a coefficient which indicates the extent to which the spatial component of the errors is correlated with one another for nearby observations. A spatial durbin model is a generalization of the SLM model which also includes spatially weighted variables as explanatory variables, and the equation is as:

$$y = \alpha + \rho Wy + X\beta + WX\theta + u, \tag{4}$$

where WX is a matrix of spatially weighted regressors, and θ is a coefficient of spatially weighted variables.

4. **Intertemporal and Spatial Crime.** This research uses the city or county specific data of National Statistics Taiwan. Variable means, standard deviations, minimums, and maximums are listed in Table 1. Data in Table 1 are calculated with city and county specific. Variable Criminal2 indicates criminal clearance cases, variable Larceny2 indicates larceny clearance cases, and variable Violence2 indicates violence clearance cases. Variable Population means number of population, variable Household means number of household, Criminal means number of criminal cases, variable Larceny means larceny cases, and variable Violence means number of violence cases. Variable Vacancy indicates vacant houses as percentage of total housing stock, variable Commerce indicates ratio of number of commercial firms to urbanized land area (km^2), variable Employ indicates ratio of number of employed persons to number of persons over the age 15, variable Tax indicates net annual revenue per capita (1000 dollars), and variable Divorce indicates divorce rate.

TABLE 1. Means and standard deviations of variables used in analyses in 2015

Variable	Mean	Standard deviation
Population	1147099	1131049
Household	407223.40	425746.60
Criminal	14492.15	13674.57
Criminal2	91.09	4.51
Larceny	3281.70	3116.32
Larceny2	83.49	8.02
Violence	96.75	86.80
Violence2	104.10	5.30
Vacancy	42975.90	35615.99
Commerce	81.54	26.32
Employ	47.06	1.54
Income	89.07	18.01
Tax	44.05	12.47
Divorce	12.41	1.75

Result of Figures 5 to 16 shows the LISA (local indicators of spatial association) cluster of variables used in this empirical research. The maps below show $p < 0.001$ and 999 permutations. "High-high" and "low-low" in the maps indicate the spatial clusters refer to the core of the cluster. However, "high-low" and "low-high" in the map indicate the spatial outliers. The cluster is classified as "spatial cluster" when the relationship at a location (either high or low) is more similar to its neighbors (as summarized by the weighted average of the neighboring values) than other locations under spatial outliers.

Results of Tables 2 to 4 show the estimation of spatial regression models on serious criminal cases in Taiwan. All models with spatial weight added in Tables 2 to 4 are more

FIGURE 5. (color online) Lisa cluster of number of criminal cases

FIGURE 6. (color online) Lisa cluster of number of larceny cases

FIGURE 7. (color online) Lisa cluster of number of violence cases

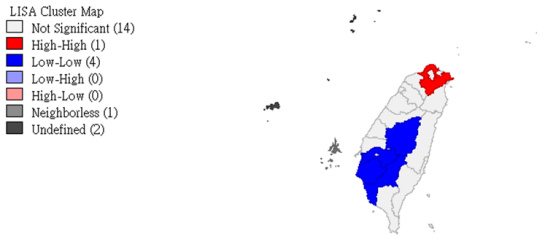

FIGURE 8. (color online) Lisa cluster of number of commerce firms

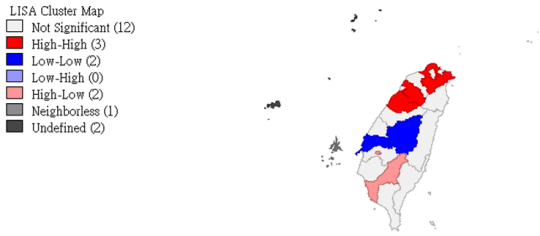

FIGURE 9. (color online) Lisa cluster of average household disposal income

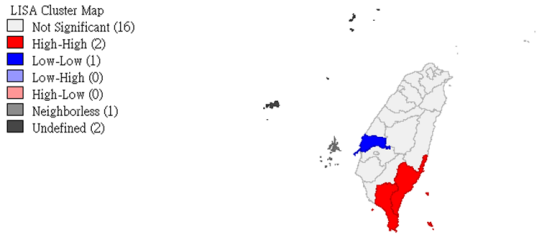

FIGURE 10. (color online) Lisa cluster of couples of divorce

FIGURE 11. (color online) Lisa cluster of number of employment over 15 years old

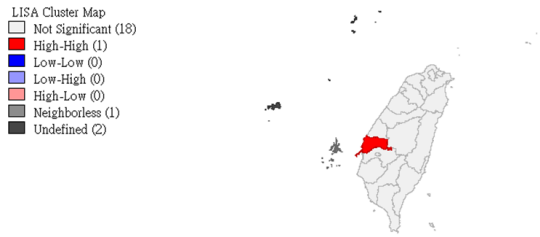

FIGURE 12. (color online) Lisa cluster of employed persons

effective than non-spatial model (ordinary least square) according to LR (likelihood-ratio) test (vs. OLS $\rho = 0$). According to the spatial regression models of serious crime cases in Table 2, Table 3, and Table 4, the result shows that estimate of log-likelihood of SDM is the highest value among the three models and it is the one selected for the investigation of statistical test on broken-windows hypothesis in Taiwan. Coefficients of Criminal2 in Table 2, Larceny2 in Table 3, and Violence2 in Table 4 are all significant at the level of

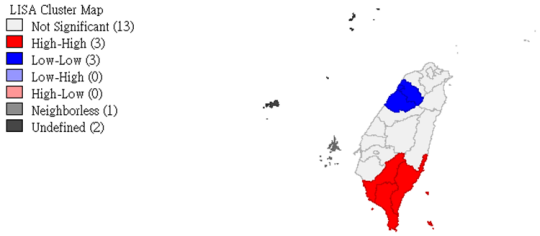

FIGURE 13. (color online) Lisa cluster of number of no spouse

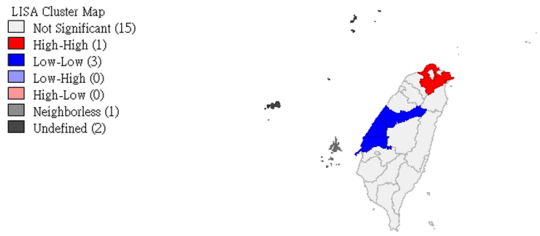

FIGURE 14. (color online) Lisa cluster of expenditure per capita of county and city

FIGURE 15. (color online) Lisa cluster of net annual revenue per capita

FIGURE 16. (color online) Lisa cluster of number of vacant house

TABLE 2. Estimation of spatial regression models of criminal cases

Variable	Model					
	SLM		SEM		SDM	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Criminal						
Constant	−57217.03*	30475.24	−70838.29***	25961.22	−73934.14***	4939.9660
Population	0.0185***	0.0056	0.0175***	0.0053	0.0073***	0.0012
Household	0.0030	0.0138	0.0037	0.013	0.0331	0.0031
Criminal2	8.6344	101.8348	15.5737	97.4087	−3.4654***	19.8278
Vacancy	−0.2617***	0.0706	−0.2387***	0.0670	−0.2266***	0.0086
Commerce	−36.2446	23.6650	−37.4782***	22.5934	−89.4514***	7.5264
Employ	999.1061**	498.7733	1256.2500***	427.6506	1465.9470***	91.1351
Income	28.1659	30.8593	32.1417	29.8481	−15.8128***	4.3488
Tax	94.6021	59.5066	105.3241*	56.6349	97.7455***	4.7672
Divorce	689.5154**	286.3440	783.9769***	270.0501	1132.6740***	65.5261
W_Population					0.0119***	0.0013
W_Household					−0.0186***	0.0052
W_Criminal2					−108.8384***	18.8144
W_Vacancy					0.0090**	0.0035
W_Commerce					56.3196***	2.4177
W_Employ					−35.1168	32.0731
W_Income					−8.1992***	0.9510
W_Tax					45.2669***	6.7798
W_Divorce					114.0297**	45.3267
W_Criminal	0.0092**	0.0037	0.0042***	0.0013	−0.4270***	0.0350
F	67.1478***		54.9853***		369.0957***	
Log-Likelihood	−177.2414		−176.7713		−118.1305	
R^2 adjust	0.8719		0.8658		0.8986	
LR Test vs. OLS ($\rho = 0$)	4.2338**		5.2427**		148.7418***	

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

TABLE 3. Estimation of spatial regression models of larceny cases

Variable	Model					
	SLM		SEM		SDM	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Larceny						
Constant	4181.9990	6079.896	3344.76	5223.7621	−22555.81***	5418.3560
Population	0.0004	0.0010	0.0003	0.0009	−0.0036***	0.0010
Household	0.0034	0.0024	0.0035	0.0022	0.0099***	0.0020
Larceny2	−33.0171***	12.6013	−31.2370***	9.8580	−24.2073***	8.8427
Vacancy	0.0322***	0.0121	0.0347***	0.0113	0.0838***	0.0062
Commerce	−2.4364	4.1943	−3.4531	4.1604	0.0035	4.5516
Employ	−48.4785	99.6879	−33.7775*	17.3565	−425.1521***	103.0499
Income	9.2113*	5.3352	9.6107**	4.4856	27.1497***	4.6757
Tax	−7.4547	10.7434	−7.1015	7.3014	34.4627***	5.5443
Divorce	46.3555	54.0438	53.2172	44.7911	123.8853**	48.0592
W_Population					0.0026**	0.0011
W_Household					−0.0076**	0.0035
W_Larceny2					−30.4062***	9.2433
W_Vacancy					0.0412***	0.0059
W_Commerce					2.6173	2.9184
W_Employ					−7.9777	7.1765
W_Income					15.3920***	1.0300
W_Tax					16.0813***	4.8135
W_Divorce					−10.1851	15.3911
W_Larceny	−0.0008***	0.0003	−0.0143*	0.0074	−0.3986***	0.0530
F	115.3981***		100.6105***		51.0370**	
Log-Likelihood	−142.2181		−141.7872		−114.7792	
R^2 adjust	0.8835		0.8811		0.8897	
LR Test vs. OLS ($\rho = 0$)	4.0038**		3.8559**		56.4775***	

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

10 percent of significance as well as their signs are all negative. This demonstrative result shows that crime clearance is negatively correlated to criminal activities. This research concludes that broken-windows hypothesis is valid in Taiwan.

5. **Conclusions.** Serious crime rates during the period from 2005 to 2015 declined in Taiwan. This research finds the remarkable decline in serious criminal activity is attributable to improved economic conditions and deterrence measures. Consistent with the statements of Wilson and Kelling [1], in this research it uses serious criminal clearance cases as a measure of broken-windows strategy and investigates its effects, along with economic conditions and sanction on three index serious criminal activities. However, both economic and deterrence variables are important in explaining the decline, and the contribution of deterrence measures is larger than those of economic variables. One important point that needs to be considered is that significant increases in serious criminal clearance may be costly not only in terms of police resources but also because of the social costs.

The demonstrative result of this research provides a strong identification on broken-windows hypothesis in Taiwan. By using spatial regression models an investigation on the nature between crime and place would be introduced. If spatial features serve as actuating factors for crime, either because of the people who or facilities that are located there, then interventions designed to alter those persons and activities might well affect crime. Alternatively, if the spatial distribution of crime is essentially random, then targeting specific places is not likely to be an effective crime control strategy. Sorting out the

TABLE 4. Estimation of spatial regression models of violence cases

Variable	Model					
	SLM		SEM		SDM	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Violence						
Constant	−906.0463***	277.3747	−815.4920***	234.8619	−552.1067***	174.7067
Population	0.0002***	0.0001	0.0002***	0.0001	0.0005***	0.0001
Household	−0.0002	0.0002	−0.0002	0.0001	−0.0008***	0.0002
Violence2	−6.1036***	1.1520	−5.5818***	0.9827	−10.3422***	1.0653
Vacancy	−0.0027***	0.0007	−0.0026***	0.0007	−0.0067***	0.0007
Commerce	−0.3176	0.2277	−0.5566***	0.2044	−0.0945***	0.0325
Employ	28.2423***	5.3488	25.7825***	4.1752	−32.7362***	4.2254
Income	0.2251	0.3103	0.2709	0.2873	−1.7175***	0.2783
Tax	1.6700***	0.5995	1.5317***	0.5384	0.6982**	0.3410
Divorce	17.3912***	3.7983	16.0091***	3.1999	24.4307***	2.8976
W_Population					−0.0005***	0.0001
W_Household					0.0012***	0.0002
W_Violence2					2.9547***	1.0713
W_Vacancy					0.0003***	0.0001
W_Commerce					0.8064***	0.1399
W_Employ					−2.1123	1.6795
W_Income					−0.3140***	0.0683
W_Tax					−3.4327***	0.6401
W_Divorce					−0.2335	2.3434
W_Violence	−0.0595*	0.0319	0.0086		−0.2558**	0.1164
F	24.6345***		10.4767***		22.5322**	
Log-Likelihood	−85.4066		−83.7433		−63.7756	
R^2 adjust	0.8255		0.7344		0.8304	
LR Test vs. OLS ($\rho = 0$)	3.4818*		6.1600**		4.8317**	

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

place/crime relationship requires analytical methods that are best suited to isolating the impacts of place on crime. While spatial analyses remain a promising tool, the very early stage of research on the relationship between crime and place is reason for a degree of caution. Considerably more research is needed before we look to location as a primary target for crime control efforts. Both basic social science research and well-designed applied research on specific police interventions will be of value.

Further research on direct effects as well as spillover effects of explanatory variable on crime would be necessary for the investigation of spatial externality of crime by using spatial econometric models. This decomposition should be quite useful in public policy decision making.

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