



Spatio-temporal Analysis with Risk Factors for Five Major Violent Crimes

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1. Abstract

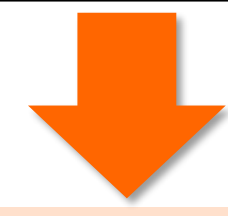
Backgrounds

- According to the National Police Agency, Seoul had the second largest number of crimes with 309,269 cases in 2019.
- In particular, the five major violent crimes including murder, robbery, rape and forced indecent act, theft, and violence accounted for one-third of all crimes with a total of 103,668 cases.
- It is important to prevent such crimes because they negatively affect all members of society such as causing distrust among members of society.



Purpose

- Develop the spatio-temporal models for examining the risk of the five major violent crimes.
- Identify risk factors that significantly affect relative risk through posterior probability.



Results and Conclusion

- The best model is selected in terms of the deviance information criteria (DIC).
- Various results such as the main effects of space-time and relative risks on the best model are shown in Figure.
- Efficient strategies can be established to sustain people's safe everyday living by analyzing the relative risk of each region.

2. Spatio-temporal Model

Count Data

$$y_{it} \sim \text{Poisson}(\mu_{it}), \mu_{it} = E_{it}\rho_{it}$$

- y_{it} : The number of five major violent crimes at district i and year t in Seoul
- μ_{it} : The mean of y_{it} observed
- E_{it} : The number of expected cases at district i and year t in Seoul
- ρ_{it} : The relative risk at district i and year t in Seoul

2.1 Classical Parametric Trend

: Linearity constraint in Temporal effect

$$\log \rho_{it} = b_0 + u_i + v_i + (\alpha + \delta_i)t + \sum_{k=0}^p \beta_k x_{itk}$$

- b_0 : Overall log relative risk in the entire study region
- u_i : Spatially structured effect, modeled using the iCAR prior

$$\mathbf{u} \sim N(\mathbf{0}, \tau_u^{-1} \mathbf{Q}^{-1}), Q_{ij} = \begin{cases} n_{ij}, & i = j \\ -1, & i \sim j \\ 0, & \text{else} \end{cases}$$

- v_i : Spatially unstructured effect, modeled using Gaussian exchangeable prior
 $\mathbf{v} \sim N(\mathbf{0}, \tau_v^{-1} \mathbf{I})$
- α : Main linear trend representing the overall temporal effect
- δ_i : Differential temporal effect
 $\delta \sim N(\mathbf{0}, \tau_\delta^{-1} \mathbf{I})$
- x_{itk} : k th risk factor observed at district i and year t
- β_k : Regression coefficient of x_{itk}

2.2 Nonparametric Dynamic Trend

: Releasing the linearity condition for the temporal effect using dynamic nonparametric formulation

$$\log \rho_{it} = b_0 + u_i + v_i + \gamma_t + \phi_t + \sum_{k=0}^p \beta_k x_{itk}$$

- γ_t : Temporally structured effect, modeled using a random walk of order 1
 $\gamma_t | \gamma_{t-1} \sim N(\gamma_{t-1}, \tau_\gamma^{-1})$
- ϕ_t : Temporally unstructured effect, modeled using Gaussian exchangeable prior
 $\phi \sim N(\mathbf{0}, \tau_\phi^{-1} \mathbf{I})$

2.3 Space-time Interaction Nonparametric Trend (Type I)

: Allowing for differences in the temporal trend of each district

$$\log \rho_{it} = b_0 + u_i + v_i + \gamma_t + \phi_t + \delta_{it} + \sum_{k=0}^p \beta_k x_{itk}$$

- δ_{it} : Space-time interaction between two unstructured effects v_i and ϕ_t
 $\delta \sim N(\mathbf{0}, \tau_\delta^{-1} \mathbf{I})$

3. Application

3.1 Materials

- The number of five major violent crimes that occurred in Seoul between 2016 and 2019 is collected. In addition, various risk factors are considered to assess and remove their effect.

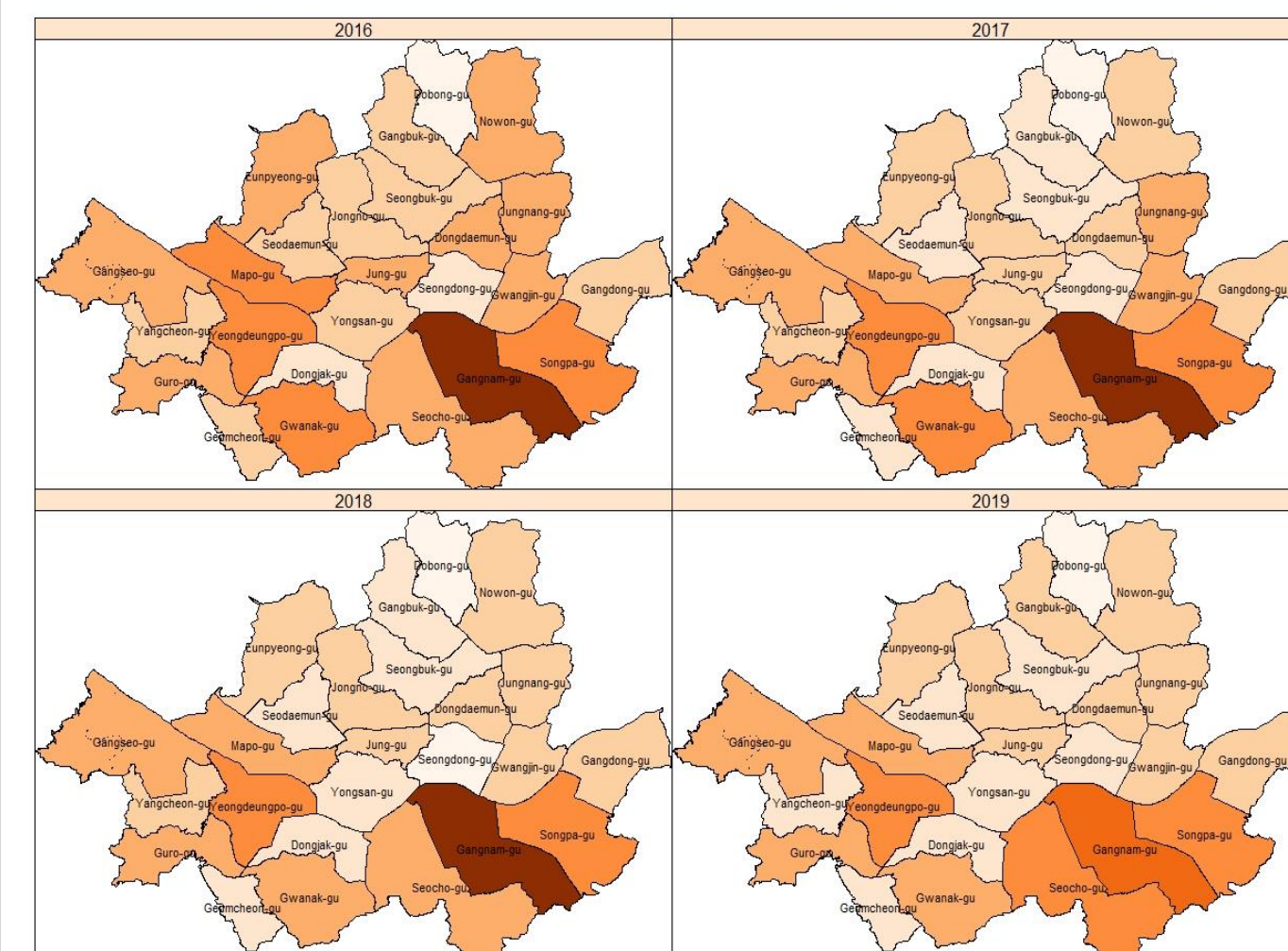
(Data Sources : Seoul Open Data Plaza and Korean Statistical Information Service)

Risk Factors (8)

- The number of CCTV (CCTV) – The number of entertainment establishments (EE)

- The number of public security facilities (SF) – Female population rate (FPR)
- Single person households rate (SPHR) – Elderly population rate (EPR)
- Safe return scout use rate (SRSUR) – The number of safe return scout staff (SRSS)

- The number of five violent crimes in Seoul between 2016 and 2019 (y_{it})



- Descriptive statistics for the risk factors

Variable	Min	Mean	Max	SD
log(CCTV)	6.27	7.47	8.65	0.49
log(EE)	4.13	5.07	6.32	0.59
log(SF)	2.30	2.87	3.26	0.24
FPR	0.49	0.51	0.53	0.01
SPHR	0.20	0.32	0.49	0.06
EPR	0.11	0.14	0.19	0.02
SRSUR	0.01	0.07	0.22	0.04
log(SRSS)	1.95	2.82	3.33	0.35

3.2 Results

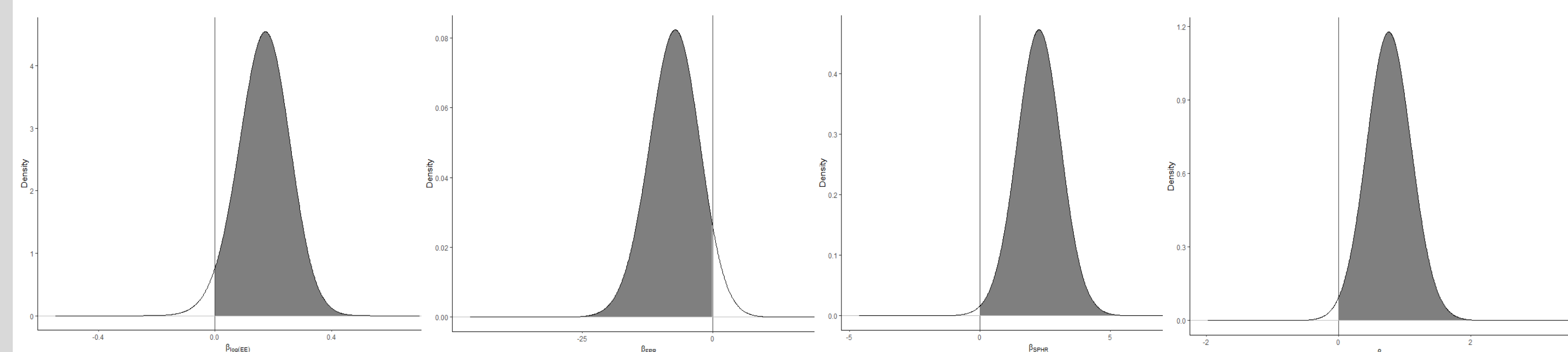
DIC

Classical Parametric Trend	Nonparametric Dynamic Trend	Space-time Interaction Nonparametric Trend
1469.80	1668.32	1211.79

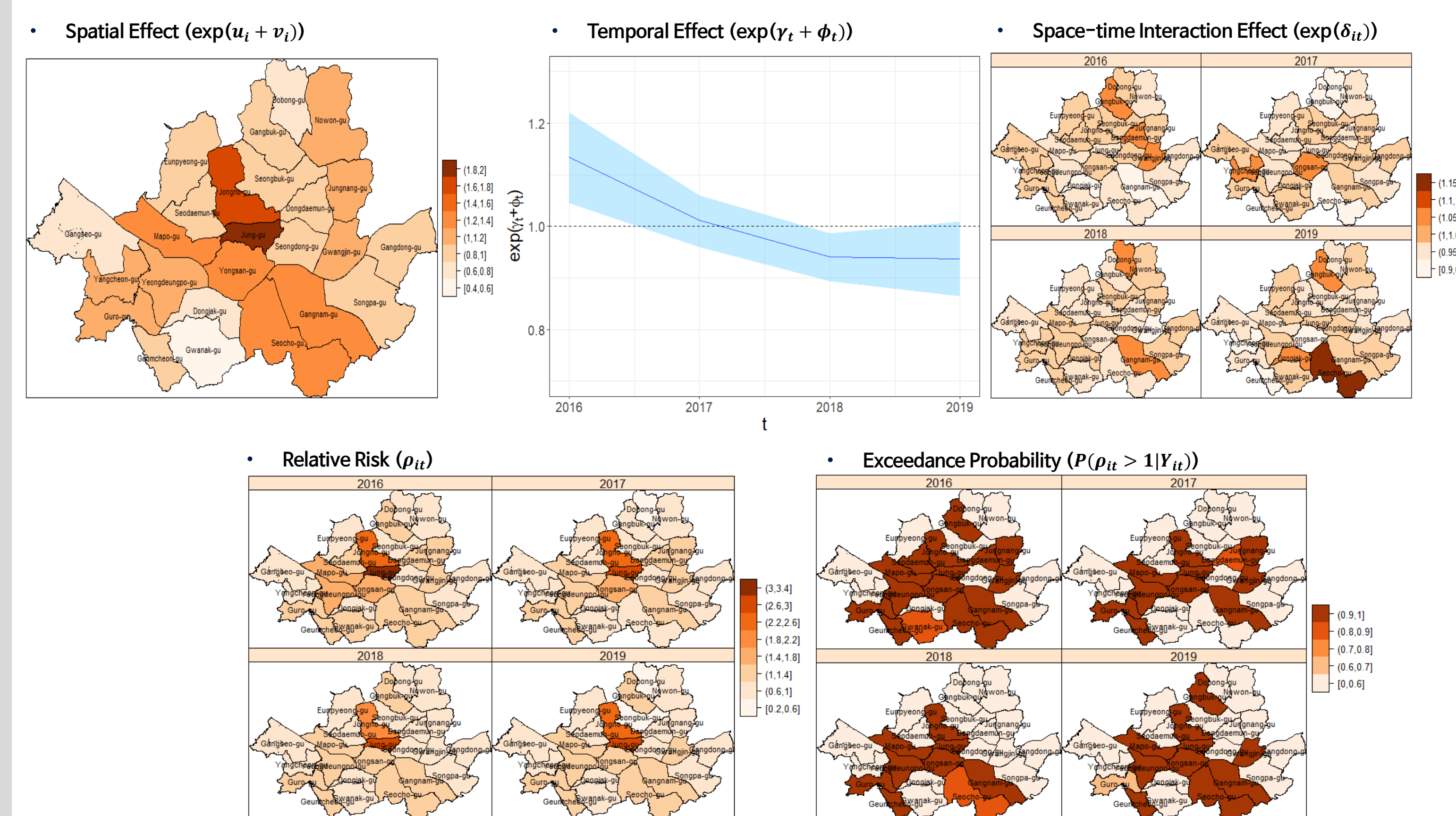
Posterior summaries for the best model

Parameter	Mean	SD	2.5%	50%	97.5%
β_0	2.287	2.673	-2.838	2.243	7.667
$\beta_{\log(\text{CCTV})}$	-0.018	0.041	-0.100	-0.017	0.063
$\beta_{\log(\text{EE})}$	0.167	0.089	-0.014	0.169	0.338
$\beta_{\log(\text{SF})}$	-0.056	0.161	-0.375	-0.056	0.259
β_{FPR}	-7.362	4.890	-17.177	-7.293	2.067
β_{SPHR}	2.249	0.859	0.544	2.253	3.932
β_{EPR}	2.003	2.403	-2.731	2.006	6.714
β_{SRSUR}	0.765	0.342	0.096	0.763	1.441
$\beta_{\log(\text{SRSS})}$	-0.042	0.037	-0.115	-0.042	0.029

Risk factors that have a significant effect



Mapping



4. Conclusions

- In terms of the DIC, the best model is the **space-time interaction nonparametric trend**.
⇒ **The relative risk of five major violent crimes increases as EE, SPHR and SRSUR increase or FRP decreases.**
⇒ **If the SPHR rises by 0.1 units, then the relative risk increases by about 25%.**
- In fact, the five major violent crimes occurred the most in Gangnam-gu, but Jung-gu has the highest relative risk, followed by Jongno-gu.
⇒ People in Jung-gu have a higher risk of five major violent crimes than in the entire region.
- Strong policies are needed in Jung-gu, which has the highest risk, such as reducing the number of EE or reviewing the location of CCTVs to prevent crimes efficiently.