

# Population-level alcohol consumption and suicide mortality rate in South Korea: An application of multivariable spatial regression model

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## Abstract

This research estimates the contextual effects of population-level alcohol consumption on the average suicide mortality rate (SMR) in South Korea from 2013 to 2015. The effect was estimated not only in relation to the risk factors of suicide, such as divorce and being elderly, but also protective factors, such as church attendance and educational attainment. Using a multivariable spatial regression model, results show that only *excessive* population-level alcohol consumption pattern had a positive effect on SMR by increasing 0.24 standardized units in the SMR; the *moderate* pattern, however, had no significant impact. These results imply that the excessive population-level alcohol consumption pattern is a risk factor with respect to SMR. This research suggests the implementation of policies to control population-level alcohol consumption, based on a concern for public health, to reduce the suicide risk in South Korea.

## Introduction

According to the World Bank, the suicide mortality rate (SMR) of South Korea (Korea) in 2016 was 26.90 per 100,000 population, the fourth-highest worldwide (World Bank, 2016). In the past few decades, researchers have attempted to identify

underlying causes for Korea's high SMR by applying different theoretical and methodological frameworks (Lee *et al.*, 2010; Lee and Kwon, 2015; Yoon *et al.*, 2015). Most research has considered individual-level characteristics, such as depression and other psychological disorders, lack of adaptive skill and substance abuse, as major determinants for suicidal behaviour; few have examined contextual effects (Cheong *et al.*, 2012). However, assuming that spatial variations in the SMR reflect contextual features of a location, exploring those variations has recently become a significant research concern (Yoon *et al.*, 2015). The contextual approach is based on the idea by Durkheim (1897) that suicide cannot be solely understood at the individual level because suicide, as a social fact, is a product of the cross-level interaction between the individual and society.

Based on the contextual perspective, this research explores the spatial variations of the SMR in Korea and how contextual covariates of suicide contribute to such variations. Among several contextual predictors, this research focuses on population-level alcohol consumption. As researchers have consistently noted, even though alcohol consumption does not in itself cause suicide, it does significantly affect the SMR in a complicated interaction of individual, situational and other social factors (Sher, 2005). For this reason, researchers have examined the contextual effects of alcohol consumption on the SMR in the United States (U.S.) (Ramstedt, 2001; Kerr *et al.*, 2011), Canada (Ramstedt, 2005), Russia (Pridemore *et al.*, 2013), and Europe (Ramstedt, 2001), but rarely in Korea. Although some researchers have examined the effects of alcohol consumption on suicidal behaviour in Korea, they have focused on individual-level consumption only as a control variable (Park, 2013). Therefore, this research accounts for spatial variations in the SMR by focusing on population-level alcohol consumption.

## Alcohol consumption and the suicide mortality rate

The association between alcohol consumption and suicidal behaviour has been established for both chronic and acute individual drinking patterns (Ramstedt, 2005; Landberg, 2009; Kerr *et al.*, 2011). Chronic effects have been assumed to operate through the reciprocal relationship between alcohol consumption and other individual pathologies, such as depression, whereas acute effects have been assumed to temporarily weaken the operation of constraints that prevent suicidal behaviour (Cornelius *et al.*, 1995; Kerr *et al.*, 2011). Despite these differing mechanisms, researchers have consistently found positive associations between individual-level alcohol consumption and suicidal behaviour (Cornelius *et al.*, 1995). At the contextual level, relying on the findings of individual-level studies, but not being trapped in ecological fallacies, researchers have focused on the changes in per capita consumption as a proxy for population-level alcohol consumption. They have assumed that the changes in per capita consumption indicate both the frequency of intoxication occasions and the prevalence of

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*heavy drinking in a population* (Landberg, 2009: p.453). These two population-level indicators are assumed to be parallel to the two mechanisms of acute intoxication and chronic abuse at the individual level. Consequently, researchers have found a positive association between per capita consumption and SMR (Landberg, 2009) by utilizing time-series statistical techniques (Ramstedt, 2005; Landberg, 2009; Kerr *et al.*, 2011; Phillips, 2013; Pridemore *et al.*, 2013). For instance, Kerr *et al.* (2011) examined 53 years of data between 1950 and 2002 from 48 U.S. states with time-series techniques while controlling for unemployment rates. They found that the increase of total alcohol consumption had a significantly positive effect of 2.3% per litre on the SMR. Moreover, some researchers have found that the positive association was contingent upon a society's drinking pattern. For instance, Ramstedt (2001) examined 14 European countries with times-series statistical methods and found that the per capita consumption was in general positively associated with the SMR. However, the strength and significance of the association were conditioned by the country's drinking culture. A similar culturally contingent effect of per capita consumption was found in Canada (Ramstedt, 2005).

Even though previous studies of the contextual effects of alcohol consumption on the SMR found a positive association across time and place, they did not consider other covariates that might have mediated or confounded this association (Ramstedt, 2001). Several previous studies have found a set of contextual variables that has a positive or negative effect on the SMR. Researchers have usually found that divorce (Stack, 1982; Cheong *et al.*, 2012; Yoon *et al.*, 2015), education (Durkheim, 1897; Stack, 1982; Shah and Bhandarkar, 2009), unemployment (Kerr *et al.*, 2011; Defina and Hannon, 2015), the Gini coefficients (Kowalski *et al.*, 1987; Wadsworth and Kubrin, 2007), age (Stack, 1982; Lester, 1987), gender (Phillips and Nugent, 2014) and ethnic heterogeneity (Moore *et al.*, 2014; Recker and Moore, 2016) are risk factors in the suicide rate. At the same time, researchers have consistently found that religious adherence (Stack, 1982, 1983; Bainbridge, 1989), mean income (Hooghe and Vanhoutte, 2011), effective clinical interventions (Blow *et al.*, 2004), and the health infrastructure (James and Porter, 2012) are protective factors. However, the effects of both risk factors and protective factors on suicide have not been always consistent in their direction and strength, depending on the units of analysis and methodologies (Pompili *et al.*, 2013). For example, the high level of education, which was assumed have a positive influence on the SMR by weakening the common faith within a society, sometimes showed opposite or mixed effects on suicide rate (Stack, 1998; Shah and Bhandarkar, 2009). This research estimates the contextual risk of population-level alcohol consumption on the average SMR in South Korea from 2013 to 2015. The effect is not only estimated in relation to the risk factors, such as divorce and being elderly, but also with regard to protective factors, such as church attendance and educational attainment.

## Materials and Methods

### Data source and measurement

This research examines several datasets publicly available at the Korean Statistical Information Service database (KOSIS, 2017). For the dependent variable, the SMR, this research obtains cause-of-death data from the annual statistics between 2013 and

2015. The dataset provides the SMR per 100,000 population in different geographic regions. Suicide is relatively rare in many countries that might be unduly influenced by random fluctuations; thus, this research uses the average SMR between 2013 and 2015 (Wadsworth *et al.*, 2014). In addition, this research uses Korean administrative units, Si (cities)-Gun (counties)-Gu (districts), as the units of analysis. The Si-Gun-Gu divides Korea into 250 units. Thus, the average SMR between 2013 and 2015 for each 250 Si-Gun-Gu in Korea is examined in light of alcohol consumption, divorce, church attendance, and education attainment. For contextual variables, such as population-level alcohol consumption and other socioeconomic predictors, this study uses datasets available at the KOSIS. All datasets were collected in 2015. The statistics on alcohol consumption compiled by the Ministry of Health and Welfare provide the percentage of population with different frequencies and prevalence rates of heavy drinking. In the dataset, consumption is measured as low (at least once a month) and excessive (women who drink more than three or men who drink more than five cans of beer more than twice a week) drinking pattern. Even though these two indicators do not directly present the per capita alcohol consumption in previous studies, they demonstrate what the concepts of per capita consumption indicate: *both the frequency of intoxication occasions and the prevalence of heavy drinking in a population* (Landberg, 2009: p. 453). Thus, two levels of consumption in the dataset are used as proxies for the population-level alcohol consumption.

In addition, church attendance is indicated by the percentage of population who believe in any religious denominations, including Buddhism, Protestantism, and Catholicism. The divorce rate is the percentage of population who is divorced. Drawing on Stack (1998), this research measures education not only by the percentage of population with at least a college degree, but also by the percentage of people with at least a college degree who are unemployed. Ethnic heterogeneity is measured by the percentage of population whose nationality is not Korean. Moreover, as a proxy for the health infrastructure (human and physical resources intended to alleviate the mortality rate), this research includes the number of psychiatrists per 10,000 population in each geographic unit.

### Analytical strategy

Researchers have consistently pointed out that traditional studies assuming non-independence of observations have failed to consider that the influence of structural conditions spills over into adjacent neighbourhoods (Baller *et al.*, 2001). These spillover effects are often larger than those of structural covariates themselves, and the covariates are *severely constrained by the spatial context of adjacent neighbourhoods* (Morenoff *et al.*, 2001; p. 552). Thus, this research considers the spillover effects of spatially proximate units by using a two-pronged spatial analysis to examine the structural covariates of the SMR in Korea (Baller *et al.*, 2001). The first phase of this research explores the spatial distribution and clustering of the SMR with several thematic maps and Moran's *I* and Anselin's local indicator of spatial association (LISA) (Moran, 1950; Anselin, 1995; Anselin *et al.*, 2006). Moran's *I* shows a possible global spatial dependence in the SMR across Korea; the LISA produces a categorical outcome indicating positive or negative clustering at a more localized level. In the second phase, with spatial dependence in the model, this research identifies whether that spatial dependence is caused by either error or lag. When the dependence is caused by error, or by omitted variables, the spatial weight is applied to the error

term in the regression equation (spatial error model). The error model can be presented as:

$$Y = X\beta + \varepsilon, \quad \varepsilon = \lambda W\varepsilon + \mu \quad \text{Eq. 1}$$

where Y is the dependent variable; X the independent variable;  $\varepsilon$  the vector of error terms; W the spatial weight;  $\lambda$  the autoregression parameter; and  $\mu$  the vector of uncorrelated, homoscedastic errors (Baller *et al.*, 2001).

When the spatial dependence is associated with substance (lag), or with the dependent variable by itself, the spatial weight is applied to the dependent variable (spatial lag model). The spatial lag model can be presented as:

$$Y = \rho WY + X\beta + \varepsilon \quad \text{Eq. 2}$$

where  $\rho$  is the autoregression parameter; W the spatial weight; and  $\varepsilon$  the error term (Baller *et al.*, 2001). The term  $\rho WY$  indicates that the variation of Y in a specific unit is affected by the spatially weighted values of Y in adjacent units. The spatial lag model indicates that the outcome variable depends not only on the independent variable within a location, but also on that of other neighbouring locations (Baller *et al.*, 2001). Thus, depending on the result of the spatial dependency diagnostics using Lagrange multiplier (LM) statistic (Anselin and Rey, 1991), this study chooses one of these two models and analyzes the datasets with four additive multivariable spatial regression models.

In addition, this research applies the first order of queen as the spatial weight across spatial analyses because it indicates strong dependence than other orders of queen. Here, the queen contiguity is a type of spatial weight, which estimates the proximity of observation based on a common border or common vertices of each geographic unit of analysis (Maravi *et al.*, 2017). When producing thematic maps for the visualization of variables, this research uses the Jenks natural breaks classification method, which minimizes each class's average deviation from the class mean and maximizes each class's deviation from the means of other groups (Chen *et al.*, 2013). Finally, this research uses the GeoDa1.12.1.59 for spatial regression analyses (Anselin *et al.*, 2006) and QGIS 2.18.19 for data visualization.

**Table 1. Descriptive statistics on variables.**

Variables	Minimum	Maximum	Mean	Standard Deviation	Moran's I
Outcome variable					
Suicide Mortality Rate (per 100,000 population)	15.1	63.5	30.6	7.9	0.52***
Explanatory variables					
Moderate Drinking (%)	34.2	69.1	55.8	6.4	0.67***
Excessive Drinking (%)	9.8	30.5	19.1	3.4	0.14**
Risk factors					
Divorce Rate (%)	2.8	9.3	4.8	1.1	0.38***
Population over 65 (%)	5.4	36.6	17.6	7.8	0.63***
Ethnic heterogeneity (%)	0.3	26.5	2.6	2.8	0.36***
College Degree or more (%)	7.2	49.8	17.7	7.8	0.65***
Unemployed College Degree (or more) holders (%)	16.6	54.5	33.3	5.8	0.12*
Protective factors					
Church Attendance Rate (%)	33.0	58.4	44.0	4.4	0.45***
Number of Psychiatrists (per 10,000 population)	0.0	46.4	6.3	6.5	0.05

\*P<.05; \*\*P<.01; \*\*\*P<.001.

## Results

### Descriptive statistics

This research first analyzed the characteristics of each variable (summarized in Table 1).

Next, this research uses thematic maps to explore the spatial distribution of the SMR and the alcohol consumption indicator with the Jenks natural breaks classification. As seen in Figure 1, the SMR in the geographic units is unevenly distributed, evidenced by the fact that the high SMR is concentrated in the north-eastern and mid-western areas of Korea. Similarly, the percentage of population with excessive drinking patterns is clustered in the similar areas with a high SMR, as seen in Figure 2.

### Spatial autocorrelation and clustering in the suicide mortality rate

There is also a statistically significant amount of spatial autocorrelation in the SMR. SMRs in the units are far from random, as evidenced by the positive slopes of the Moran's I coefficient (0.425). The positive slope indicates when the SMR increases within a unit, those of neighbouring units also increase. In addition to Moran's I coefficients for SMR, as seen in Table 1, the coefficients for independent variables are found statistically significant with relatively high values.

Based on the strong global spatial dependence, this research examines potential clustering at the local unit in reference to the LISA. As seen in Figure 3, the 18 spatial units with a High-High relationship and the 14 units with a Low-Low relationship indicate positive association between the SMR of a unit and those of its neighbours. These 32 units significantly contribute to the positive global spatial autocorrelation. At the same time, the four units with a Low-High and High-Low relationship significantly contribute to a negative autocorrelation outcome. These results additionally demonstrate that the SMR in Korea is not randomly distributed at the local level. These spatial dependences and clusters are proper indicators not only for descriptive purpose, but also for multivariable spatial regression analysis (Porter and Purser, 2010).

### Multivariable spatial regression models

This research also identifies the appropriate spatial model to control for the presence or absence of spatial dependence by testing whether the dependence is caused by error or lag (Baller *et al.*, 2001). Running the ordinary least squares model in the GeoDa package, this research chooses the error model because the LM coefficients in the four models in Table 2 indicate that the error model has more significant value than the lag model (Anselin and Rey, 1991; Anselin *et al.*, 2006). Table 3 presents the LM test results for Model 4. With this model specification, this research estimates the contextual effects on the SMR, as seen in Table 2. For all models, the spatially correlated error indicator ( $\lambda$ ) has a positive effect with a high significance.

In Model 1, this research tests the isolated effect of the alcohol consumption indicator on the SMR. This research finds that a one-unit increase in the percentage of population with an excessive

drinking pattern significantly and positively affects the SMR by 0.61 units, but a one-unit increase of moderate drinking pattern does not significantly influence the SMR. These significant or non-significant effects of two drinking patterns remain constant across all models.

In Models 2 and 3, this research includes the five risk factors of suicide as control variables. In Model 2, this research finds that both the divorce rate and the percentage of elderly population strongly and positively influence the SMR, evidenced by the high coefficient values, 1.55 and 0.63, respectively. Their effects on the SMR remain constant across all models with some slight changes in their coefficients. This research finds that the effects of education produce mixed results, depending on employment status. The percentage of unemployed people with college degrees positively affects the SMR, but the percentage of people with college degree negatively affects the SMR. Finally, this research incorporates the

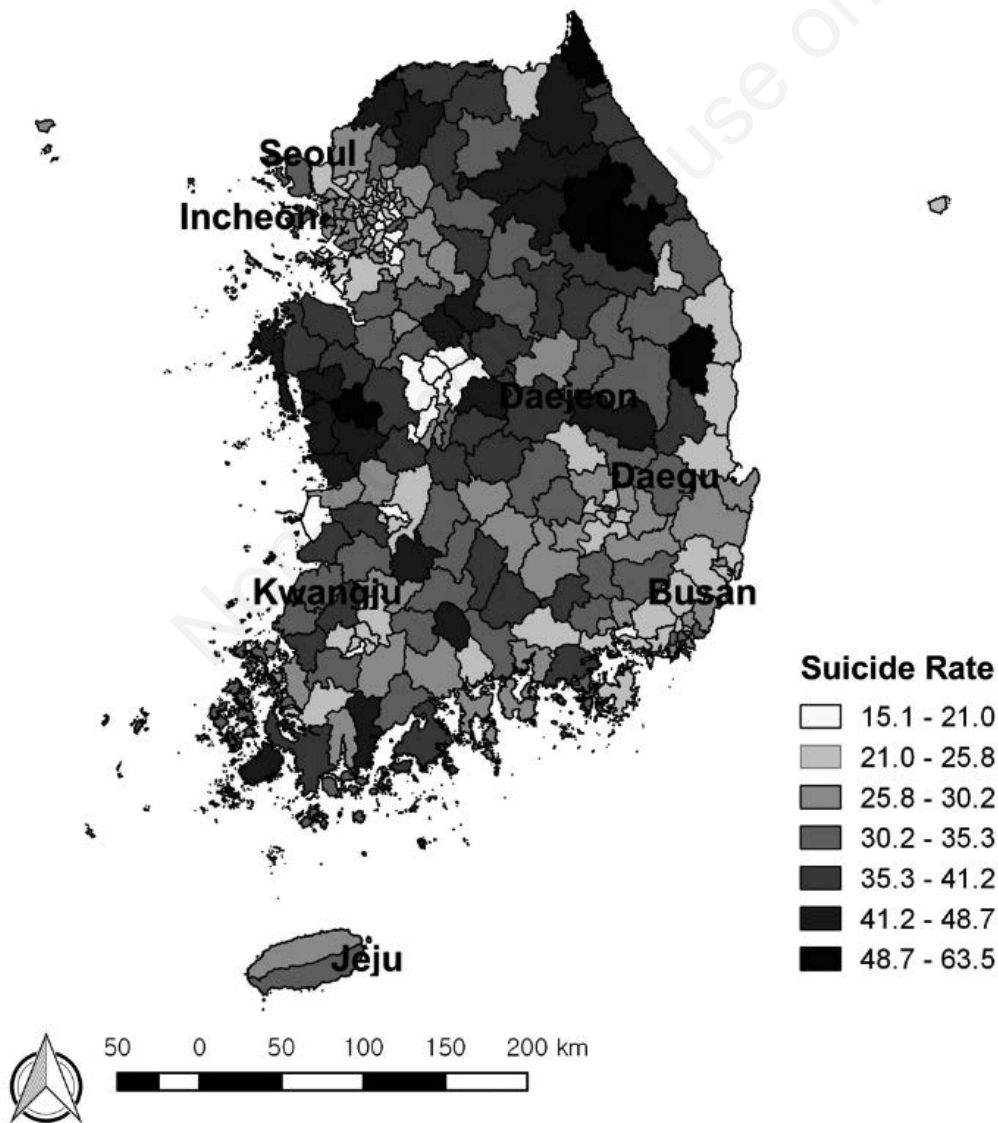
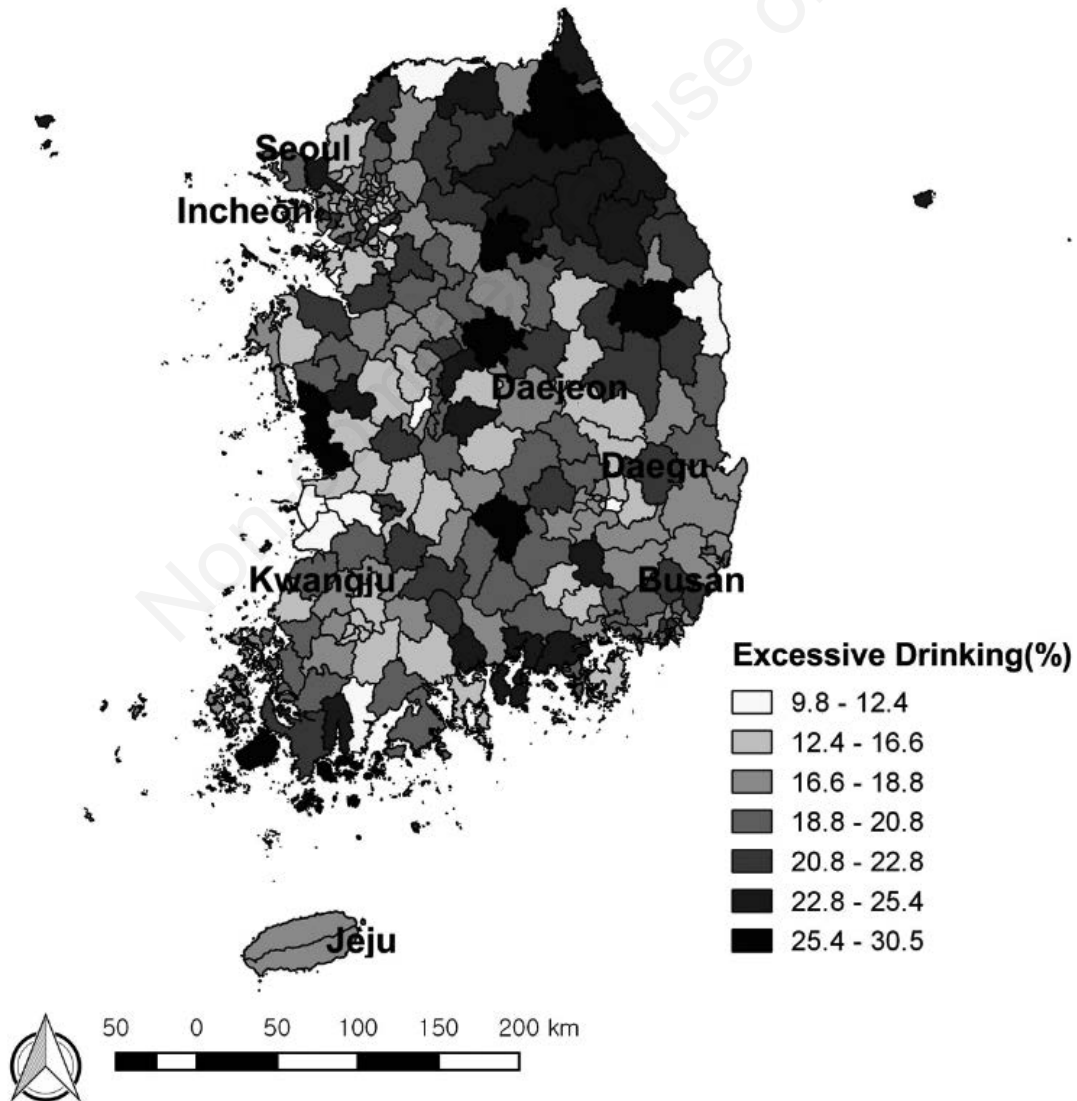


Figure 1. Spatial distribution of the suicide mortality rate (per 100,000 population) in Korea.

**Table 2. Spatial error models explaining the contextual covariates of suicide mortality rate.**

Structural Covariates		Model 1	Model 2	Model 3	Model 4
Alcohol Consumption	Moderate (%)	0.03	0.03	0.02	0.03
	Excessive (%)	0.61***	0.30**	0.22*	0.24*
Risk Factors	Divorce Rate (%)	-	1.55***	0.81*	1.00**
	Age over 65 (%)	-	0.63***	0.43***	0.57***
	Ethnic Heterogeneity (%)	-	0.01	-0.02	0.01
	College Degree (%)	-	-	-0.37***	-0.22**
	Unemployed College Degree Holders (%)	-	-	0.12*	0.15**
Protective Factors	Church Attendance (%)	-	-	-	-0.25**
	Psychiatrists (per 10,000)	-	-	-	-0.09
Constant		17.29***	4.39	16.00***	20.58***
Spatial Parameter ( $\lambda$ )		0.48***	0.44***	0.44***	0.45***
R-Square		0.35	0.57	0.62	0.64
Akaike's information criterion		1659.73	1558.66	1531.67	1524.74
Moran's I for Residuals		-	-	-	-0.002

\*P<.05; \*\*P<.01; \*\*\*P<.001.



**Figure 2. Spatial distribution of population with excessive alcohol consumption.**

two protective covariates of suicide as control variables in Model 4. Examination of these features reveals that on the one hand, church attendance rate negatively affects the SMR by decreasing 0.25 units of the SMR. On the other hand, the negative effect of number of psychiatrists on the SMR is marginally significant (P-value: 0.07). The addition of all variables to Model 4 produces the best model fitness with the highest R-square and the lowest Akaike's information criterion values. Additionally, the non-significant value of Moran's *I* for residuals in the Model 4 indicates that the spatial dependence in the model was controlled by the application of spatial error model.

ed that the distribution of SMR was spatially dependent in Korea, and that the population with excessive drinking patterns positively influenced SMR after controlling for other risk factors and protective factors of suicide. It was estimated that a one-unit increase in the population with excessive drinking pattern is associated with a 0.24- unit increase in the SMR. These findings are congruent with the results of previous studies which found a positive association between per capita alcohol consumption and the SMR in different locations (Landberg, 2009; Kerr *et al.*, 2011).

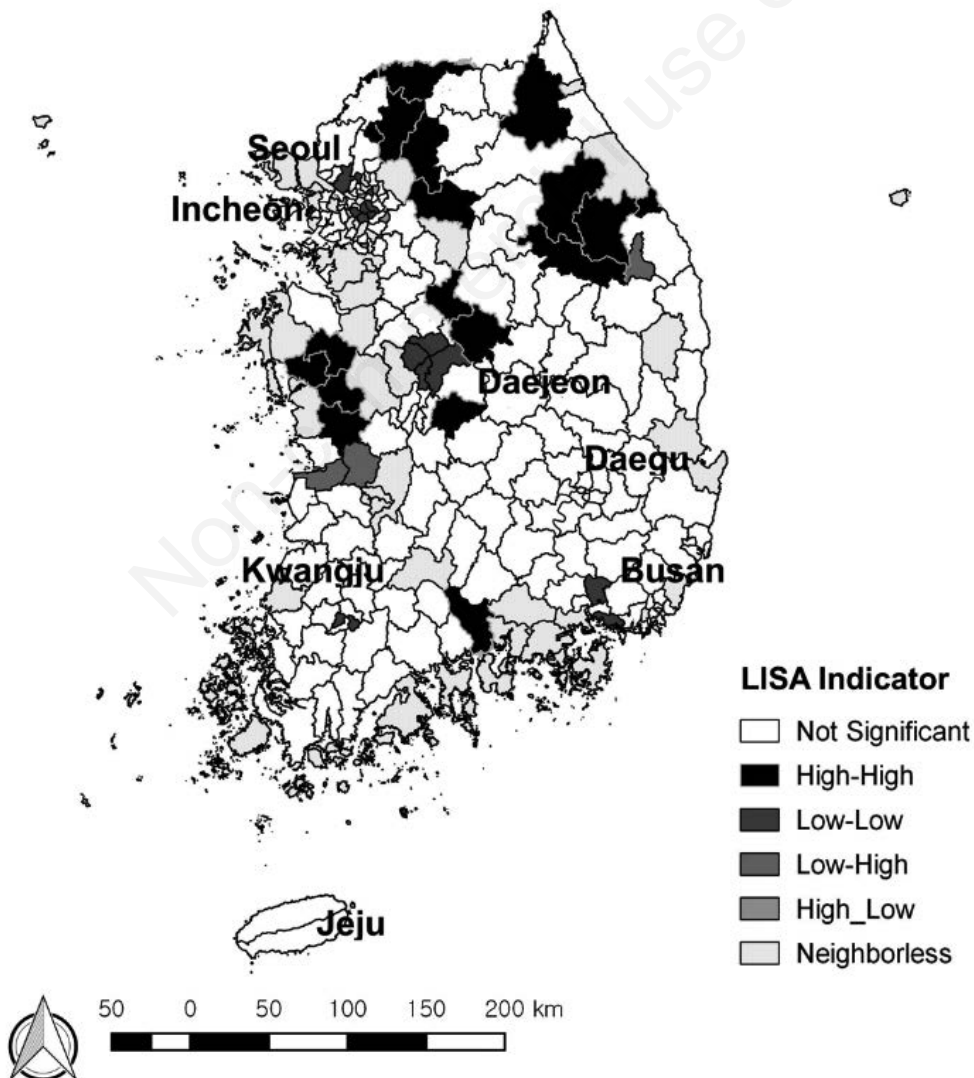
### Discussion and Conclusions

This research identified the contextual effects of population-level alcohol consumption on the SMR in Korea by controlling for risk factors and protective factors of suicide. This research indicat-

**Table 3. Results for Lagrange multipliers (LM) for Model 4.**

Test	MI/DF	Value	Probability
LM (lag)	1	7.9028	0.0049
Robust LM (lag)	1	0.5070	0.4764
LM (error)	1	40.6304	0.0000
Robust LM (error)	1	22.2346	0.0000

MI, Moran's *I*; DF, degree of freedom.



**Figure 3. Anselin's local indicator for spatial association (LISA) for the suicide mortality rate.**

Therefore, as previous researchers have noted (Blow *et al.*, 2004; Pridemore, 2013), an effective alcohol policy, including anti-alcohol campaigns or clinical interventions, need to be implemented in Korea to alleviate the deteriorating contextual effects of alcohol consumption on public health. As Seo *et al.* (2015) pointed out, Korea's approach to alcohol control policy has centred on regulating the alcohol beverage industry out of economic interest, not based on a concern for public health. This conclusion is indirectly supported by the finding of this study that the number of psychiatrists marginally, but negatively, affected Korea's SMR. However, these findings and interpretations need to be understood strictly at the contextual level, because the ecological fallacy does not allow researchers to draw inferences about individual behaviour from results based on aggregate data, or vice versa (Robinson, 1950).

One interesting finding in this research was that the effects of education on the SMR were contingent upon employment status. As Stack (1998) noted, the discrepancy between education and the expected status resulted in more psychological anomie in Korean populations. These findings can be supported by Korea's unique educational environment where *academic success has been considered a key to success and is viewed as a survival response* (Lee *et al.*, 2010: p. 538). In this competitive educational environment, populations with high academic achievement are more likely to be frustrated when they are dissatisfied with their lives in general, as compared to the level that they had expected. In addition, unlike Durkheim (1897) who argued that the high education influences the SMR by weakening of the common faith within a society, a growing number of researchers has posited that education is associated with social or economic status (Stack, 1998; Pompili *et al.*, 2013). This emerging view accounts for the differing effects of education in Korea where the high level of education in general leads to social success (Stack, 1998; Lee *et al.*, 2010).

This research has the following strengths. It tested the effects of population-level alcohol consumption on suicide in Korea, a topic that has been rarely explored. In addition, this research identified several contextual covariates of the suicide rate beyond alcohol consumption; these findings supported that the contextual impact of alcohol consumption needs to be understood in terms of the interaction of individual, situational, and other social factors (Ramstedt, 2001; Sher, 2005). Furthermore, this research considered the spatial autocorrelation in examining those effects. Assuming that these findings are accurate, this research concludes that Korea belongs to the group of countries whose population-level alcohol consumption is positively associated with its SMR.

Nevertheless, there are some limitations in this research. This research considered the SMR for the entire population of Korea. As previous researchers have found, per capita alcohol consumption influenced the SMR of different demographic groups in different ways (Ramstedt, 2001; Pridemore *et al.*, 2013). Thus, gender- or age-differing effects of alcohol consumption on the SMR in Korea need to be explored. Moreover, even though this research considered structural covariates beyond population-level alcohol consumption, it might have omitted variables that could affect the association, such as population-level depression (Lee and Kwon, 2015) and the use of antidepressants (McKeown *et al.*, 2006). Thus, future studies need to incorporate other possible structural covariates of the suicide rate.

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