



# Spatial modelling and mapping of teen birth rates in Taiwan in the period 1995-2010

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## Abstract

Geographical variations in teen birth rates (TBR) still persist despite controlling for contextual factors. The aim of this research was to identify spatial patterns of TBR in Taiwan and to examine spatial relationships among different contextual factors. Using townships as the unit of analysis ( $N=359$ ), this research used social and demographic variables for the years 1995, 2000, 2005 and 2010 and conducted spatial modelling of TBR. Geographical maps of TBR were presented, and Local Indicator of Spatial Autocorrelations was used to identify TBR clustering. Comparisons were made between ordinary least-squares models and spatial lag models, in which township-level TBRs were regressed on other township-level contextual characteristics. Our study found that townships with a high TBR were mostly in eastern, central and some southern regions of Taiwan, while townships with a low TBR were in the vicinity of metropolitan areas. The

significant spatial lag indicated that townships would have a higher expected prevalence rate if adjacent townships have had higher rates. Results also indicated that the percentage of aborigines and the percentage of college-educated people were consistently associated with TBR over the years. Interventions aimed at reducing TBR in Taiwan should consider the presence of spatial correlations and should incorporate neighbouring townships.

## Introduction

The teen birth rate (TBR) has dramatically declined across Taiwan in the past two decades changing from 17 births per 1,000 teens in 1990 to 4 births per 1,000 teens in 2010 (Government, 2016). The country has a population of nearly 23 million distributed over a geographical area of about 36,193 km<sup>2</sup> (13,974 sq mi). Despite its small geographical size, local variations in TBRs still persist with declines exhibiting marked regional differences. In 2010, the TBRs for some rural townships in Taiwan were about 10 times higher than those in metropolitan areas such as Taipei City (Government, 2016). Most prior studies on teen pregnancy and birth focus on individual- and interpersonal-level risk factors and prevention programmes emphasizing knowledge and personal decision-making rather than contextual influence on teen pregnancy (Maness and Buhi, 2016). Still, identification of contextual risk factors related to TBR, as well as its geographical distribution, is important in providing clues to causal pathways of increasing gaps in TBRs among regions (Salazar *et al.*, 2010; Gunaratne *et al.*, 2015). Some sociological theories have suggested possible explanations regarding spatial heterogeneity in TBRs (Shaw and McKay, 1969; Shoff and Yang, 2012). Possible explanations include differences in community norms, collective efficacy, health service provision and the employment environment. Moreover, previous studies have identified population density, divorce rate, education and healthcare resources as significant contextual factors (Sampson *et al.*, 1997; Sampson and Raudenbush, 1999; South and Crowder, 2010). Population density was negatively related to the general birth rate in population studies, but was also related to elective abortions among teenagers (Lutz *et al.*, 2006). The community-level divorce rate has been linked to the prevalence of adolescent risk behaviours, such as violence, substance use and teen pregnancy (Carlson *et al.*, 2014). The racial or ethnic composition of an area may also be related to the TBR, since it has been shown that race and ethnicity differ with regard to age of the first birth and also reflect the fact that marginalized populations are more likely to live in disadvantaged neighbourhoods and therefore exposed to risk behaviours (Shirley and Long, 2004; Mollborn, 2010). These aforementioned contextual factors could further affect how indi-

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viduals utilize local health services, including contraceptive use, or how they react to stress and unsafe environment, even how they manage teen pregnancy and births (Mollborn, 2010). In this study, we identified spatial patterns of TBRs using a geographical information system and spatial modelling to examine spatial relationships among different contextual factors (Yao *et al.*, 2012). Most previous ecological studies focused only on the influence of factors in the immediate residential community. However, communities are embedded in a larger system of geographical areas, and it is possible that adolescents who live in surrounding communities can share social and institutional ties, which can affect local norms of teen pregnancy (South and Crowder, 2010). This has been recognized in prior studies studying the diffusion effects of teen pregnancy due to social interaction of people living in nearby areas (South and Crowder, 2010). The objective of this study was to assess the influence of adjacent or otherwise proximate communities on TBR with the expectation that findings could provide additional insights on factors influencing TBR that may lead to new approaches in designing interventions.

## Materials and Methods

This study was a repeated cross-sectional study for the years 1995, 2000, 2005 and 2010, using township, county-level city, and districts as the units of analysis. Briefly, the administrative structure in Taiwan, from large to small in terms of population size, has the following geographical hierarchy: special municipality, provincial city, county-level city, and township. To provide a basis of comparison, the minimum population sizes for special municipalities and provincial cities were 1,250,000, and 500,000, respectively. Special municipalities and provincial cities can be further divided into districts, usually with a population size of <200,000. The county-level city, which is one level below the provincial city, has a minimum population of 150,000 but no more than 500,000, while townships have populations less than 150,000. Hence, for this research, townships, county-level cities and districts were used as the administrative units of analysis since they were similar with regard to population size. Many health and social service sources are allocated at this level, and previous research have pointed out that heterogeneity in socioeconomic conditions, racial composition and health outcomes is present within these geographical units (Hung *et al.*, 2009). In total, 359 townships, county-level cities and districts (hereafter referred to as townships) were included in the analysis.

## Data source and measurements

The outcome variable was TBRs, defined as live births per 10,000 women aged 15–19 years and log-transformed for normality. The explanatory variables included population density (number per km<sup>2</sup>), percentage of the aboriginal population, percentage of the elderly population, percentage of the college-educated population, number of physician per 10,000 persons, social welfare spending per person and the divorce rate, which was calculated as the number of divorced and separated persons over the number of people aged ≥15 years. Data used to generate these variables were retrieved from multiple sources of official government statistics: Household Registration Statistics, City and County Statistics and Census (Ministry of Finance, Taiwan, 2016). The Household Registration Statistics provided data on the age and sex distribution of the population within townships. The City and County Statistics provided data on births, marriages and divorces, as well as healthcare resources and social expenditures, while the Census provided information on educational attainment and ethnicity.

## Analysis

We used ArcGIS (ESRI, Redlands, CA, USA), to create maps and conduct analysis of spatial TBR patterns according to Tatem *et al.* (2014), and Global Moran's *I* (Cressie, 1993) to examine spatial autocorrelations of the TBRs (Uthman, 2008). Since Global Moran's *I* does not identify individual clusters, Local Indicator of Spatial Autocorrelation (Anselin, 1995) was used to identify particular townships clustering with high and low TBRs. This approach was specifically used to identify significant townships where both the target township and its neighbours had high values (high-high hot spots) or both had low values (low-low cold spots). In the multivariate analysis, we compared both the Ordinary Least Squares (OLS) models and spatial lag models in which township-level TBRs were regressed on other township-level demographic and socioeconomic characteristics (Vogt *et al.*, 2014). The decision that spatial lag models were selected instead of spatial error models was based on the Lagrange-multiplier test (Anselin and Bera, 1998) and the robust Lagrange-multiplier test (Anselin and Bera, 1998). Both tests suggest that the spatial lag models are more significant than the spatial error models. Spatial lag models were estimated through an autoregressive process of the dependent variable with the following equation:

$$Y = \rho WY + X\beta + \varepsilon$$

where  $\rho$  is the spatial autoregressive parameter,  $W$  a weighted matrix that expresses a form of spatial association among each pair

**Table 1. Description of contextual factors and teen birth rates by year in Taiwan.**

Variable	Year 1995	Year 2000	Year 2005	Year 2010
Teen birth rate (‰)	22.5	20	12	4
Population density (no./km <sup>2</sup> )	692.9	701.5	675.3	654.5
People >65 years old (%)	8.5	9.9	11.3	12.4
Physician density (no./10,000 inhabitants)	4.3	4.8	5.6	5.6
People divorced or separated (%)	2.7	4.2	4.3	6.7
Aborigines (%)	0.3	0.3	0.5	0.6
People with college education (%)	7.6	10.7	13.2	19.4
Social spending (NT\$/per person) <sup>a</sup>	789.8	1,515.4	848.3	971.5

<sup>a</sup>US\$1=New Taiwan (NT)\$30.



of clusters,  $X$  a matrix of exogenous explanatory variables with an associated vector of regression coefficients  $\beta$  and  $\epsilon$  a vector of normally distributed random error terms. The fitness of the model was assessed using the Quasi-likelihood Information Criterion (James *et al.*, 2017). The Variance Inflation Factor (James *et al.*, 2017) was used to check for multicollinearity in the model. The significance level of alpha was set to 5%. Prior studies suggested that 5 or 10 years can be a reasonable time difference to assess the change between two time points in larger area analyses (*i.e.*, county, state or country), and hence multivariate analyses were separately conducted for the years 1995, 2000, 2005 and 2010 for comparative purposes with the aim to observe changes in the influence of predictors over time (Chuang *et al.*, 2013).

We originally intended to include data of 2015 as well; however, this was not done since TBRs and their geographical distribution steadied after 2010, and the introduction of some major changes in Taiwan's administrative structure after 2010, especially with reference to township boundaries.

## Results

Table 1 shows the level of TBRs and contextual variables for the four years under study. The average TBR rates per township declined from 22.5 per 1,000 adolescent women in 1995 to 20 in 2000, and then continued to decline to reach as low as 4 in the year 2010. In the same period, all indicators investigated, with the exception of population density, showed an increasing trend. Social expenditures increased significantly in the year of 2000 because of the establishment of the emergency relief fund for a serious earthquake (Jiji, 1999).

Descriptive maps were constructed based on quintiles using the TBRs of 1995 as the standard (Figure 1). Even if the TBR rates in general decreased significantly over the study period, some townships in the eastern and central regions of the country still had high TBRs in 2010, indicating the presence of geographical variations. Indeed, the values of the Global Moran's  $I$  of the TBRs were 0.587 in 1995, 0.520 in 2000, 0.456 in 2005, and 0.258 in 2010, which revealed significant spatial autocorrelations as evidence of a non-random distribution of TBRs in Taiwan. The estimated local

Moran's  $I$  values are shown in Figure 2. In 1995, high TBRs (hotspots) were mostly seen in eastern, central, and some southern regions of Taiwan, and low TBRs (coldspots) in the proximity of the cities of Taipei and Kaohsiung. Over the years, especially in 2010, the coldspots strongly decreased in size, while the hotspots remained in the central, eastern and southern regions of Taiwan. However, they too appeared to be shrinking in size.

Table 2 shows Spearman's correlation coefficients between TBRs and other characteristics in 1995. Social welfare spending was the only variable not significantly associated with TBR. The correlation coefficients ranged from small ( $r=-0.030$ ) to large ( $r=0.757$ ). Table 3 summarizes results of the OLS and spatial lag models for TBRs by year. The R-squared values showed that spatial lag models explain more variance in TBRs than OLS models, which was evident for all four years studied. The spatial lag models explained 77.1%, 71.3%, 71.5% and 54.2% of the variation in TBRs for 1995, 2000, 2005, 2010, respectively (compared to 75.6%, 70.3%, 70%, 52.3%, respectively, using OLS models). The Akaike Information Criterion (Bozdogan, 1987) and Log likelihood statistics also showed better model fit for spatial lag models compared to the OLS models. For the OLS model in 1995, percentage of elderly ( $\beta=0.0393$ ), divorce rates ( $\beta=0.1293$ ), percentage of aborigines ( $\beta=0.0089$ ), population density ( $\beta=-0.0252$ ), social welfare

**Table 2. Spearman correlations of contextual factors and teen birth rates in 1995 in Taiwan.**

Variable	Teen birth rate
Teen birth rate (%)	1.000
Population density (no./km <sup>2</sup> )	-0.359*
People >65 years old (%)	0.148*
Physician density (no./10,000 inhabitants)	-0.268*
People divorced or separated (%)	0.394*
Aborigines (%)	0.757*
People with college education (%)	-0.555*
Social spending	-0.030

\*P<0.05.

**Table 3. Multivariate analysis of contextual factors on teen birth rates by year in Taiwan.**

Model	Year 1995		Year 2000		Year 2005		Year 2010	
	OLS <sup>a</sup>	Slag <sup>b</sup>						
Population density (no./km <sup>2</sup> )	-0.0252*	-0.0188*	-0.0371*	-0.0304*	-0.0208*	-0.0138*	-0.0103	-0.0041
People >65 years old (%)	0.0393*	0.0309*	0.0274*	0.0227*	0.0318*	0.0228*	0.0112	0.0058
Physician density (no./10,000 inhabitants)	-0.0012	-0.0017	-0.0032	-0.0032*	-0.0026	-0.0030	0.0000	-0.0002
People divorced or separated (%)	0.1293*	0.0886*	0.0767*	0.0645*	0.0109	0.0035	0.0390	0.0212
Aborigines (%)	0.0089*	0.0081*	0.0059*	0.0053*	0.0101*	0.0084*	0.0129*	0.0110*
People with college education (%)	-0.0547*	-0.0489*	-0.0388*	-0.0363*	-0.0525*	-0.0474*	-0.0397*	-0.0363*
Social spending (NT\$/per person) <sup>a</sup>	-0.3450*	-0.2095	0.0141	0.0129	-0.0507	-0.0208	0.1082	0.1322
Spatial lag term		0.185*		0.145*		0.202*		0.221*
R <sup>2</sup>	0.7564	0.7711	0.7038	0.7131	0.7009	0.7151	0.523289	0.5420
Akaike Information Criterion	245.481	227.856	323.927	316.067	426.66	414.176	677.008	668.21
Log likelihood	-114.741	-104.928	-153.963	-149.034	-205.33	-198.088	-330.504	-325.105

\*P<0.05; <sup>a</sup>OLS, Ordinary Least Squares; <sup>b</sup>Spatial Lag model.

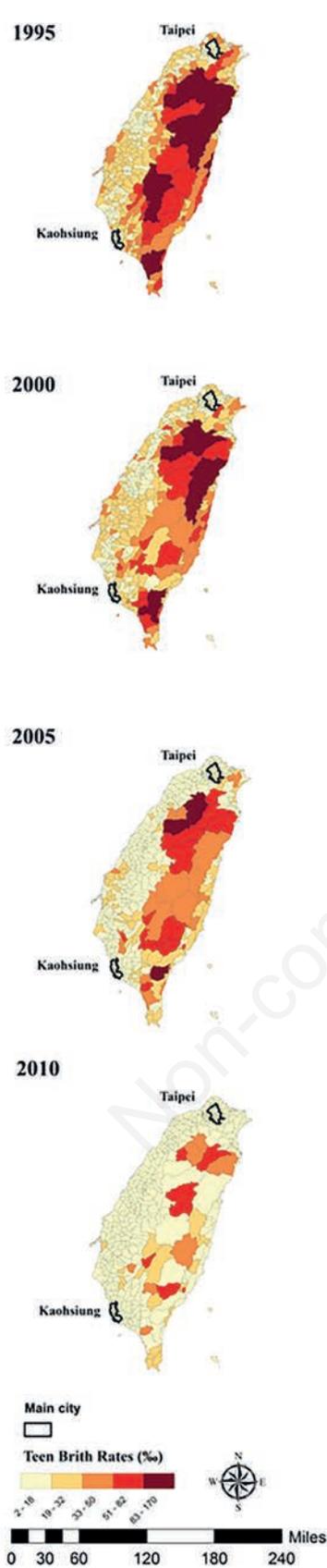


Figure 1. Teen birth rates in Taiwan by year.

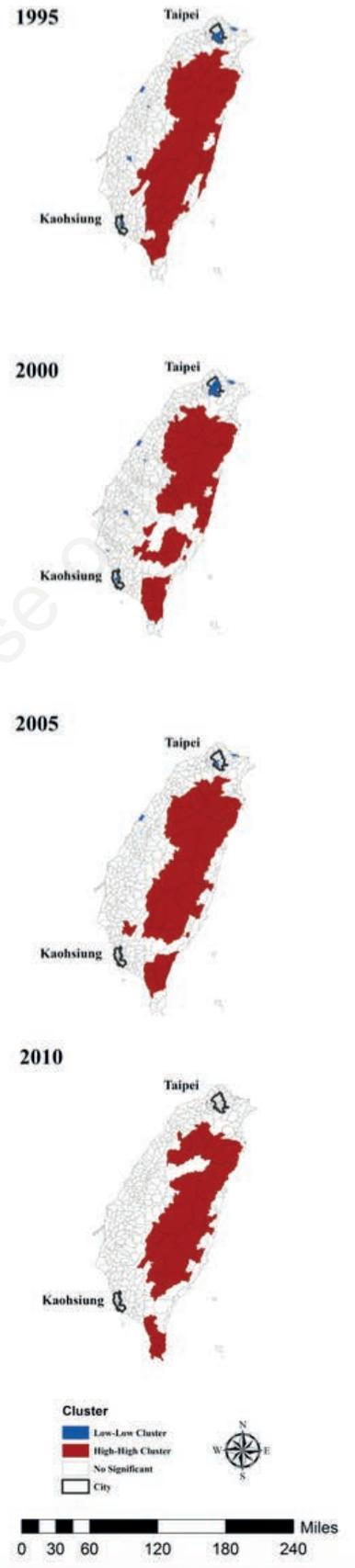


Figure 2. Local Moran's *I* values of teen birth rates in Taiwan by year.



spending ( $\beta=-0.345$ ) and percentage of college-educated people ( $\beta=-0.0547$ ) were found to be associated with TBRs. Compared to the OLS model, the spatial lag model showed similar results in 1995 with the exception of social welfare spending. In the 2000, 2005, and 2010 models, the variables that were significant in the OLS model remained significant in the spatial lag model as well but were smaller in magnitude. Overall, fewer township-level factors were significantly associated with TBRs in 2010 compared to models from earlier years (Table 3). Only two variables, the percentage of aborigines and the percentage of college-educated people were consistently associated with TBR over all the years covered by the analysis. The spatial lag term was statistically significant in every spatial lag model, which indicates that a township had a higher expected prevalence rate if adjacent townships also had higher rates.

## Discussion

This study revealed that spatial lag models could estimate the relationship between township-level risk factors and TBR more accurately than the OLS model, indicating that a township would have a higher expected prevalence rate if adjacent townships also had a higher rate. In Taiwan, the educational system may have played a crucial role in linking TBRs across township boundaries. Based on test scores, teenagers may end up attending schools in nearby townships or in other counties, instead of within their own local community. Cross-township peer groups develop quickly and hence, values and subcultures, such as attitudes towards sexual behaviour and teenage pregnancy could disseminate across township borders readily. Overall, the extent of cross-township social exchange among teenagers in Taiwan is probably much more frequent than that arising due to other educational systems, *e.g.*, those where most students attend local high schools. Cross-township peer groups and social exchange may enhance the spatial correlations of TBRs found in Taiwan.

Another interesting finding was that the influence of community-level predictors on TBRs has diminished over the years. This study revealed that health resources, such as the physician ratio and social welfare spending, had stronger associations with TBRs in earlier years, but became non-significant in later years. The implementation of the National Health Insurance program in 1995 has increased access to health care in rural areas, which has ameliorated the problem of inequality of health and welfare resources among townships. This possibly explains why we found that resource-related factors were no longer significantly associated with TBRs in Taiwan after 2000.

As previously reported, TBRs in Taiwan show geographical variations with the highest TBRs found in the central and eastern regions of Taiwan (Hung *et al.*, 2009). Over the years, the influence of demographic factors, as well as health and welfare resource factors, have tended to decrease. However, the percentage of aborigines and the percentage of higher-educated people continue to be significantly associated with TBRs. There are 16 different aboriginal tribes in Taiwan (Lee *et al.*, 2013) and these people all face difficulties in current Taiwanese society. Their average household income is <40% of that of the general population and they have a 8-year lower life expectancy compared to the general population. The anthropological literature points out that most aboriginal tribes have the custom of early marriage, and exhibit characteristics of matriarchal societies (Tsai and Wong, 2004). Moreover, a large majority of aboriginals are Christians and tend to have an

unfavourable predisposition toward abortion. It appears that once they become pregnant, adolescent aboriginal females, compared to other non-aboriginals, are more likely go through with the birth rather than have an abortion. Similar differences between adolescent Hispanic and white females in the US are reported (Shirley and Long, 2004).

A low community education level, particularly in Taiwan, is traditionally regarded as an important contextual disadvantage (Li and Chuang, 2009). Confucian culture places great emphasis on higher education and the cost of higher education in Taiwan is quite inexpensive (Chou and Ching, 2012). Hence, communities with a low percentage of college-educated people are likely to be deprived of educational resources, which creates a vicious circle where general aspirations, expectations for higher education and skilled job positions are too low to retain or attract college-educated persons. In such communities, conventional norms cannot be maintained, local basic organizations collapse and a high proportions of people become isolated from the job network system, resulting in a higher likelihood of adolescent risk behaviours (Wilson, 1987).

This study has several limitations. The selection of indicators was limited by the availability of data from government sources and hence, the research may have excluded some relevant variables previously identified to be associated with TBRs, such as the unemployment rate, which was not available at the township level. Inclusion of the unemployment rate would provide better control of economic factors in the analysis. Second, this was a repeated cross-sectional study, and therefore, the causal relationship between township-level variables and TBRs should be interpreted with caution. In particular, relationships of social spending and the divorce rate with TBRs could be bi-directional. Finally, the results can only be generalized at the township level.

## Conclusions

Two factors predicted TBRs in the different time periods consistently: the percentage of aborigines and the percentage of the higher-educated population, the former negatively (higher rates) and the latter positively (lower rates). Significant associations of TBRs among neighbouring townships were observed, even after controlling for other contextual factors.

Future interventions to reduce TBRs in Taiwan would likely be more successful if they considered the presence of spatial correlations and treated neighbouring townships jointly, rather than focusing on individual townships.

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