Spatial Variations in Covariates on Marriage and Marital Fertility: Geographically Weighted Regression Analyses in Japan

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Abstract (134)

To understand the determinants of raising fertility rates after 2005 in Japan, this study investigates the spatial variations of the relationship between changes in marriage and marital fertility, and the relationships with covariates using geographically weighted regression models. Our sample is 1,853 towns and villages based on 2010 administrative boundaries. The indexes of marriage and marital fertility are made by the standardized method. The dependent variables are the standardized marital population ratio (SMR) and the marital fertility ratio (MFR). As for the explanatory factors, we focus on female labor force participation, the sex ratio, and childcare availability. All coefficients for covariates on SMR have statistically significant geographical variations. But for MFR some coefficients didn't have significant. The female labor force participation and childcare availability show a positive relationship with MFR in the urban areas.

Introduction

Regional patterns in Japanese fertility are characterized as "Low in the metropolitan areas, higher in the non-metropolitan areas" trends came to be observed from 1950 to 2005. Since the 1970s TFR showed a downward trend throughout the country, but regional differences were maintained. After 2005, TFR went from 1.26 in 2005 to 1.39 in 2010. Our goal is to analyze the determinants of raising fertility rates after 2005 in Japan and explore the spatial variations in marriage and marital fertility how covariates relate with regions.

Investigating the cause of such variations by region may provide an important perspective to explain marriage and marital fertility. In general, social behavior is not spatially homogeneous, which indicates that individuals are influenced by a "spatial" effect. Previous research using regression analysis without taking spatial correlation and non-stationarity across regions into account may have led to an inaccurate inference. Our study first examines the spatial autocorrelations for variables relevant to marriage and marital fertility, and then applies geographically weighted regression methods to assess heterogeneity of the relationship between regional marriage and marital fertility and their covariates.

Data and Methods

The sample is 1,853 towns and villages based on 2010 administrative boundaries. The dependent variables are the standardized marital population ratio (SMR) and the marital fertility ratio (MFR) (**Figure 1 and 2**). The explanatory variables include female labor participation, the sex ratio for SMR model, childcare for MFR model and so on. Descriptive statistics of variables are shown in **Table 1**.

$$SMR = \frac{M}{\sum_i m_i P_i}, \quad SFR = \frac{B}{\sum_i b_i P_i}, \quad MFR = \frac{SFR}{SMR}$$

where *i*: age i, *M*: Marital Population, m_i: age-specific marital rates in standard population, *B*: number of births, b_i: age-specific birth rate, P_i: age-specific standard population

To assess heterogeneity of the relationship between regional fertility rates and their covariates, we applied geographically weighted regression (GWR). GWR extends to the traditional regression model by allowing the estimation of local rather than global parameters (Brunsdon et al. 1996; Fotheringham et al. 2002).

Basic model: $y_i = \beta_0(i) + \beta_1(i)x_{1i} + \beta_2(i)x_{2i} + \ldots \beta_n(i)x_{ni} + \varepsilon_i$

Parameter: $\hat{\beta}(i) = (X(X^T W(i) X)^{-1} X^T W(i) Y$

where ***W(i)***: n by n spatial weighting matrix

GWR model is assuming that observed data near to point *i* have more of an influence in the estimation of the values located farther from *i*. The equation measures the relationships in the model around each point *i*. The weights are defined as continuous functions (kernel functions) of distance that the closer a data point is to the calibration point, the greater is its weight in the estimation of the parameters for that calibration point. We have selected an adapted bi-square function model.

Results and Discussion

Table 2 shows the descriptive statistics of the GWR results. From the results of Leung et al.' s F-test (**Table 3**), all coefficients for covariates on SMR have statistically significant geographical variations. But for MFR some coefficients didn't have significant. The female labor force participation and childcare availability show a positive relationship with MFR in the urban areas (**Figure 3**). For SMR model, the sex ratio is a positive relationship in the urban areas where are low sex ratios.

These results indicate that marriage and marital fertility responses to external forces may vary across regions influenced by their historical and geographical settings, and results of the global model may not be appropriate to uniformly apply for each region. In addition, the result from our study suggests that there should be some unique circumstances that ease, reverse or accelerate the usual relationships in the area where coefficients show a difference from the area surrounding them.

Reference

Brunsdon, C., Fotheringham, A.S., and Charlton, M., 1996, "Geographically Weighted Regression: A Method for Exploring Spatial Nonstationarity", *Geographical Analysis*, No.28, pp. 281-298.

Fotheringham, A. S., Brunsdon, C., and Charlton, M., 2002, *Geographically Weighted Regression: The Analysis of Spatially Varying Relationships*, New York, John Wiley & Sons.

Leung, Y., Mei, C.-L., and Zhang, W.-X., 2000, "Statistical Tests for Spatial Nonstationarity based on the Geographically Weighted Regression Model", *Environment and Planning A*, 32, pp. 9-32.

Table 1 Variable List and Descriptive Statistics

Variables	Year	Source	Direction	Min	25%	Mean	Median	75%	Max
Dependent Variable									
Standardized Marriage Ratio	2010	Census		-1.023	-0.106	-0.037	-0.021	0.043	1.028
Marital Fertility Ratio	2010	Census		0.000	0.912	1.004	0.992	1.090	2.074
Independent Variable									
Proportion of Nuclear Family Household (%)	2010	Census	-	21.485	51.770	56.138	56.362	60.924	77.649
Excess Inbound Migrant Rate (%)	2010	Census, Prefecture Report	+	-0.106	-0.020	-0.003	-0.005	0.013	0.212
Employment Rate [15-49 years old, Female] (%)	2010	Census	+	37.500	58.130	62.443	62.541	66.673	82.000
Male Unemployment rate (%)	2010	Census	-	0.000	6.094	7.689	7.377	8.854	28.956
Propotion of Foreign Population (%)	2010	Census	+	0.000	0.349	0.929	0.625	1.099	20.342
Sex Ratio aged 15 - 49	2010	Census	-	76.008	99.229	105.470	104.234	109.361	251.790
The number of day-care centers per population of 100,000 aged 0 to 5 years old	2010	Social Welfare Facility Survey	+	0.000	265.250	607.072	448.400	770.200	5263.200

Table 2 The descriptive statistics of the GWR results: summary

Kernel function: Bi-square

Adaptive quantile	SMR	0.04098 (about 75 of 1853)
	MFR	0.08527 (about 158 of 1853)

Summary of GWR coefficient estimates:

Independent Variable	Model	Min.	25%	Median	75%	Max.	Global
Intercept	SMR	-1.0670	0.3283	0.7102	1.0850	2.1080	0.4281
	MFR	-0.2139	1.1350	1.3010	1.5620	2.5740	0.9169
Proportion of Nuclear Family Household (%)	SMR	-0.0090	-0.0003	0.0028	0.0065	0.0119	0.0033
	MFR	-0.0128	-0.0050	-0.0028	-0.0006	0.0101	-0.0003
Excess Inbound Migrant Rate (%)	SMR	-0.8721	0.0742	0.4791	0.8314	1.6340	0.3895
	MFR	-2.0050	-0.0366	0.5251	0.8731	2.3230	0.5558
Employment Rate [15-49 years old, Female] (%)	SMR	-0.0098	-0.0019	-0.0001	0.0022	0.0156	0.0050
	MFR	-0.0211	-0.0060	-0.0021	0.0006	0.0112	0.0007
Male Unemployment rate (%)	SMR	-0.0313	-0.0163	-0.0114	-0.0075	0.0148	-0.0094
	MFR	-0.0407	-0.0122	-0.0037	0.0032	0.0156	0.0050
Propotion of Foreign Population (%)	SMR	-0.1739	-0.0161	-0.0031	0.0074	0.0857	-0.0054
	MFR	-0.1497	-0.0133	0.0062	0.0191	0.0838	0.0007
Sex Ratio aged 15 - 49	SMR	-0.0047	0.0007	0.0021	0.0040	0.0076	0.0017
The number of day-care centers per population of 100,000 aged 0 to 5 years old	MFR	-0.0005	-0.0001	0.0000	0.0001	0.0002	0.0000

Effective number of parameters: 487.8291 (SMR), 487.8291 (MFR)

Effective degree of freedom: 1365.171 (SMR), 1365.171 (MFR)

AIC:-6375.778 (SMR), -6375.778 (MFR) , AICc: -5797.169 (SMR), -1846.647 (MFR)

Quasi-global R^2: 0.789 (SMR), 0.436 (MFR), Residual sum of squares: 2.832446 (SMR), 31.87271 (MFR)

Table 3 The results of Leung et al.' s F-test

Leung et al. (2000)	year	F	d.f.1	d.f.2	SS OLS residuals	SS GWR residuals	SS GWR improvement
F(1) test	SMR	0.4366 ***	1498.8	1846.0	8.773	2.832	
	MFR	0.6611 ***	1676.0	1846.0	55.396	31.873	
F(2) test	SMR	2.5997 ***	643.8	1846.0	8.773		5.941
	MFR	3.2753 ***	331.3	1846.0	55.396		23.524
F(3) test		F (SMR)	Numerator d.f. (SMR)	Dominator d.f. (SMR)	F (MFR)	Numerator d.f. (MFR)	Dominator d.f. (MFR)
Intercept		4.7351 ***	573.0	1498.8	1.0378	506.1	1676.0
Proportion of Nuclear Family Household (%)		6.5984 ***	576.1	1498.8	1.4477 ***	452.9	1676.0
Excess Inbound Migrant Rate (%)		2.1941 ***	501.8	1498.8	1.2651 **	372.4	1676.0
Employment Rate [15-49 years old, Female] (%)		2.6249 ***	624.2	1498.8	1.4109 ***	510.4	1676.0
Male Unemployment rate (%)		2.0153 ***	469.3	1498.8	1.5939 ***	372.0	1676.0
Propotion of Foreign Population (%)		2.3655 ***	195.1	1498.8	0.6751	126.0	1676.0
Sex Ratio aged 15-49		3.7819 ***	356.5	1498.8			
The number of day-care centers per population of 100,000 aged 0 to 5 years old					2.5574 ***	160.4	1676.0

Significance Level: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

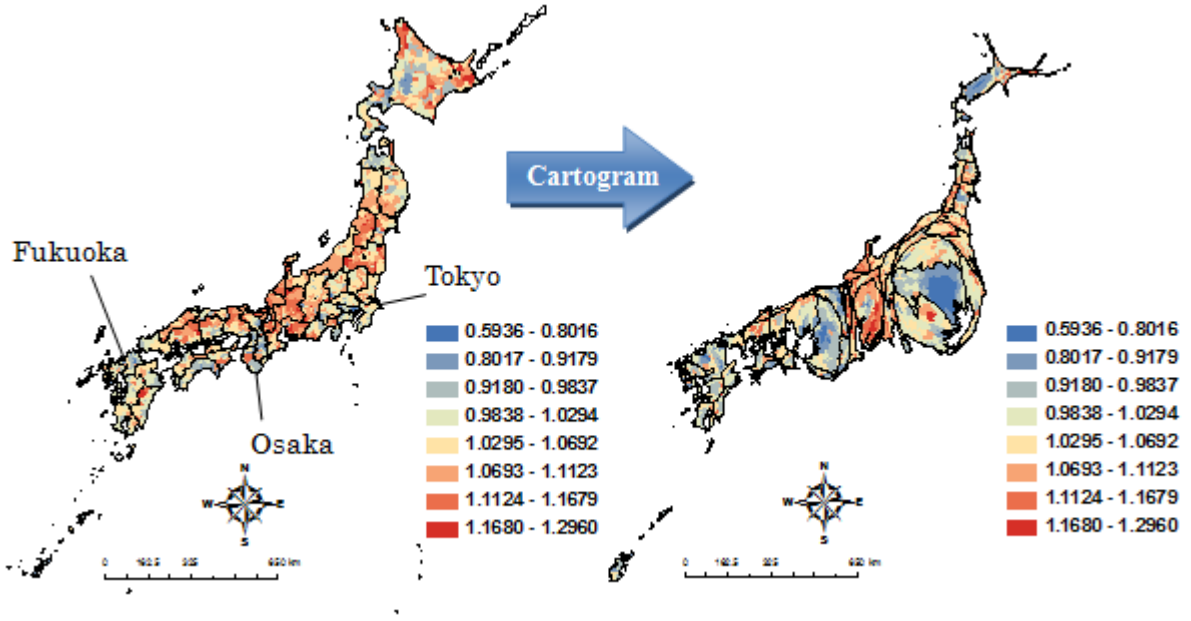

Figure 1 Distribution of SMR 2010 (Right Figure is Cartogram by Female Population aged 15-49)

※ The Cartogram is created by Gastner-Newman method using ArcGIS

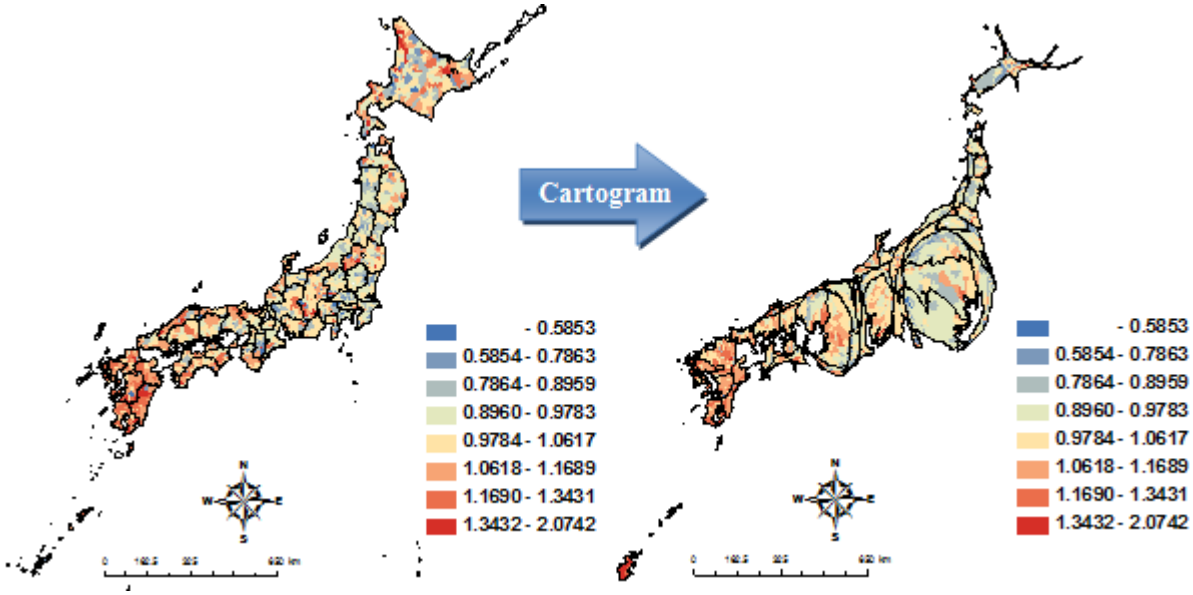

Figure 2 Distribution of MFR 2010 (Right Figure is Cartogram by Female Population aged 15-49)

※ The Cartogram is created by Gastner-Newman method using ArcGIS

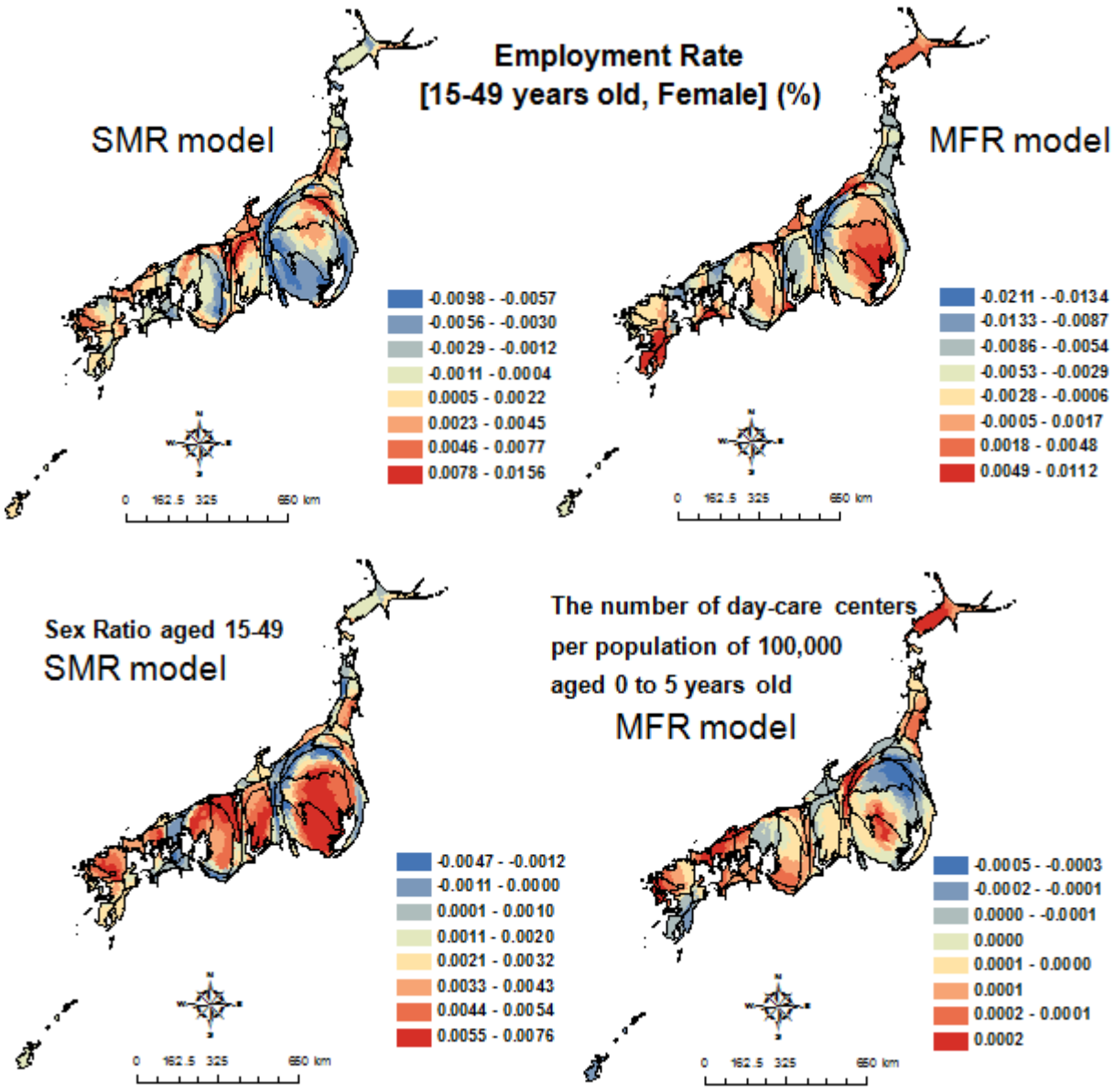

Figure 3 Distributions of Local Coefficients estimated by GWR