

Spatial Variations in Determinants of Fertility Reversal after 2005 in Japan: Geographically Weighted Regression for Small Area Estimates of TFR

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Abstract (140)

To understand the determinants of raising fertility rates after 2005 in Japan, we investigate the spatial variations of the relationship between changes in Total Fertility Rate (TFR) and their covariates using geographically weighted regression models. Our sample is 1,853 towns and villages based on 2010 administrative boundaries. Change in TFR of small area between 2005 and 2010, which is adjusted by the child-woman ratio, is used as a dependent variable. As for the explanatory factors, we focus on female labor force participation, child-care availability, economic conditions, and difference between 2005 and 2010 of these variables are introduced in the models. All coefficients for covariates on change in TFR have statistically significant geographical variations. The regional fertility rates rose markedly in the urban areas, where the increase in the female labor force participants shows positive relationship with TFR change.

Introduction

Regional patterns in Japanese fertility are characterized as "Low in the metropolitan areas, high 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. The regional fertility rates have increased in the urban areas such as Tokyo, Osaka, Fukuoka (Figure 1). Our goal is to analyze the determinants of raising fertility rates after 2005 in Japan and explore the spatial variations how covariates relate by regions.

Investigating the cause of such variations by region may provide an important perspective to explain fertility change. 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 fertility change, and then applies geographically weighted regression methods to assess heterogeneity of the relationship between regional fertility and their covariates.

Data and Methods

The sample is 1,853 towns and villages based on 2010 administrative boundaries. The dependent variable is TFR that is standardized by the child-woman ratio (Yamauchi 2009). The explanatory variables include female labor participation, the number of child-care, economic conditions and so on. Each variable is calculated as differences between 2005 and 2010. Descriptive statistics of variables are shown in Table 1. TFR in small area is calculated by the formulation below (Yamauchi 2009).

$$TFR^i = \frac{sCWR^i}{CWR^I} \times TFR^I, \quad sCWR^i = CWR^i \times \frac{P^i(0-4, t) \times \frac{5I_0}{I_0^i}}{\sum_x \{P^{i,f}(x, t) \times \alpha^I(x)\}}, \quad \alpha^I(x) = \frac{\sum_{n=0}^4 B^I(x-n, t-n)}{P^{I,f}(x, t)}$$

where I : standard population (2010), i : population i , $sCWR$: age-adjusted CWR by the indirect standardization, P : population, f : female population, L : life table function

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

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

where $W(i)$: an 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

The result suggests that the residuals of the traditional OLS model show strong spatial autocorrelation (Moran's $I = 0.126$), indicating that statistical inference can be unreliable. From GWR estimation, all coefficients for covariates on TFR have statistically significant geographical variations (Table 2 and Table 3). The regional fertility rates raised in the urban areas, where the increase of the female labor force participants has positive relationship (Figure 2). On the other hand, political measure on child care does not show positive relationship. It suggests that availability of child care is still limited in urban areas.

We conclude that fertility response 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

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- 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.
- Yamauchi, Masakazu, 2009, "The new indirect estimation method of TFR using standardized CWR", *The Journal of Population Studies* (Jinkogaku Kenkyu), No.45, pp.35-44. (in Japanese)

Table 1 Variable List and Descriptive Statistics

Variables	Year	Source	Direction	Min	25%	Mean	Median	75%	Max
Dependent Variable									
Total Fertility Rate [※]	2005-2010 difference	Census, Vital statistics		-1.023	-0.106	-0.037	-0.021	0.043	1.028
Independent Variable									
Proportion of Never-married Population [30-39 years old, Female] (%)	2005-2010 difference	Census	-	-11.129	1.686	3.196	3.045	4.548	28.325
Proportion of Nuclear Family Household (%)	2005-2010 difference	Census	-	-12.415	-1.195	-0.035	-0.127	1.125	15.183
Excess Inbound Migrant Rate (%)	2005-2010 difference	Census, Prefecture Report	+	-0.199	0.003	0.023	0.020	0.041	0.329
Employment Rate [15-49 years old, Female] (%)	2005-2010 difference	Census	+	-12.042	5.951	7.459	7.358	8.764	26.411
Male Unemployment rate (%)	2005-2010 difference	Census	-	-8.953	0.300	1.057	1.030	1.862	8.059
Proportion of Foreign Population (%)	2005-2010 difference	Census	+	-3.783	-0.061	0.054	0.030	0.140	11.314
The number of day-care centers per population of 100,000 aged 0 to 5 years old	2005-2009 difference	Social Welfare Facility Survey	+	-992.300	0.000	41.913	29.500	84.200	824.400

※Indirect estimation method of TFR using standardized CWR (Yamauchi 2009)

Table 2 The descriptive statistics of the GWR results: summary

Kernel function: Bi-square

Adaptive quantile: 0.0777(Band Width=154.0791)

Summary of GWR coefficient estimates:

Independent Variable	Min.	25%	Median	75%	Max.	Global
Intercept	-0.1182	0.0318	0.0741	0.1200	0.3637	0.0781
Proportion of Never-married Population [30-39 years old, Female] (%)	-0.0350	-0.0167	-0.0129	-0.0076	0.0076	-0.0135
Proportion of Nuclear Family Household (%)	-0.0503	-0.0054	0.0029	0.0084	0.0487	-0.0021
Excess Inbound Migrant Rate (%)	-1.6230	-0.2101	0.1790	0.3339	1.9580	0.1107
Employment Rate [15-49 years old, Female] (%)	-0.0442	-0.0118	-0.0055	0.0019	0.0157	-0.0073
Male Unemployment rate (%)	-0.0555	-0.0150	-0.0075	0.0004	0.0333	-0.0080
Proportion of Foreign Population (%)	-0.2656	-0.0662	-0.0199	0.0043	0.1364	-0.0184
The number of day-care centers per population of 100,000 aged 0 to 5 years old	-0.0012	-0.0004	-0.0003	-0.0002	0.0001	-0.0003

Effective number of parameters: 320.9834, Effective degree of freedom: 1532.017

AIC: -2802.336 (OLS: -2170.404) , AICc : -2478.864

Mean of R2: 0.505, Residual sum of squares: 20.94461

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

Leung et al. (2000)	F	d.f.1	d.f.2	SS OLS residuals	SS GWR residuals	SS GWR improvement
F(1) test	0.7574	1622.7	1845.0 ***	33.304	20.945	
F(2) test	2.1876	430.9	1845.0 ***	33.304		12.359
F(3) test	F	Numerator d.f.	Dominator d.f.			
Intercept	2.5819	475.2	1622.7 ***			
Proportion of Never-married Population [30-39 years old, Female] (%)	1.7300	384.8	1622.7 ***			
Proportion of Nuclear Family Household (%)	2.7711	380.2	1622.7 ***			
Excess Inbound Migrant Rate (%)	1.9822	364.8	1622.7 ***			
Employment Rate [15-49 years old, Female] (%)	2.7232	434.7	1622.7 ***			
Male Unemployment rate (%)	1.4556	396.5	1622.7 ***			
Proportion of Foreign Population (%)	1.4477	164.2	1622.7 ***			
The number of day-care centers per population of 100,000 aged 0 to 5 years old	1.6408	157.6	1622.7 ***			

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

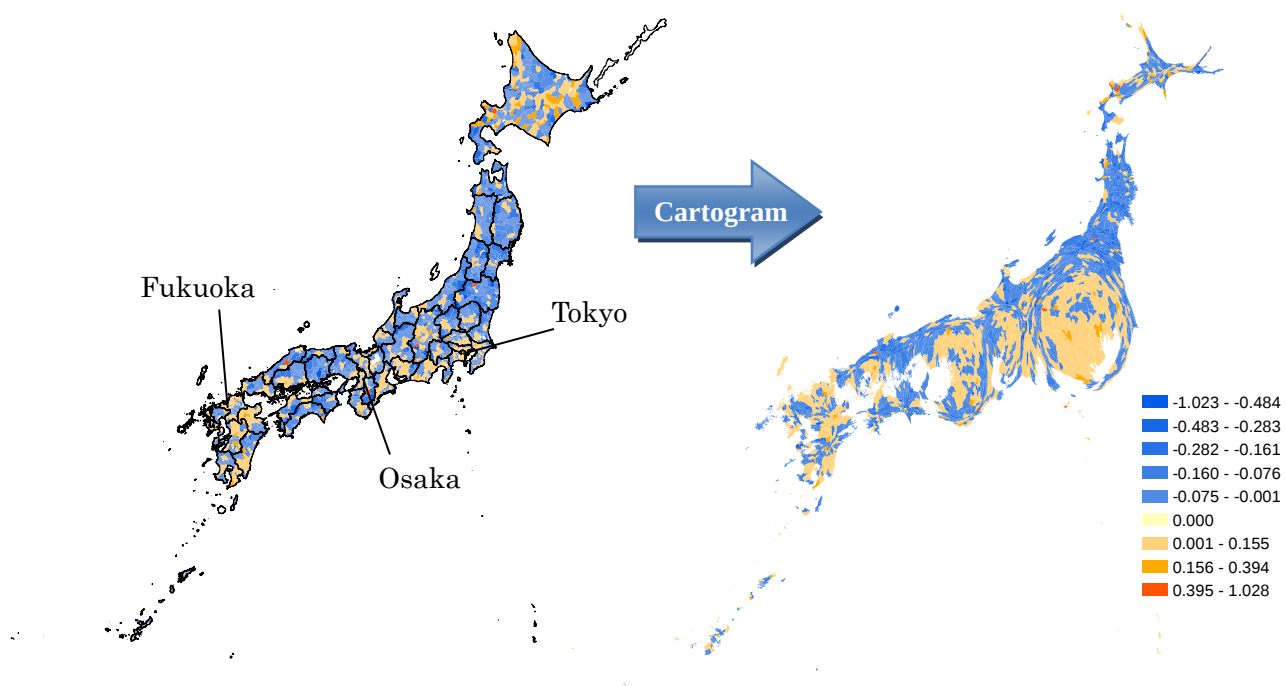


Figure 1 TFR difference between 2005 and 2010 (Right Figure is Cartogram by Total Population)

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

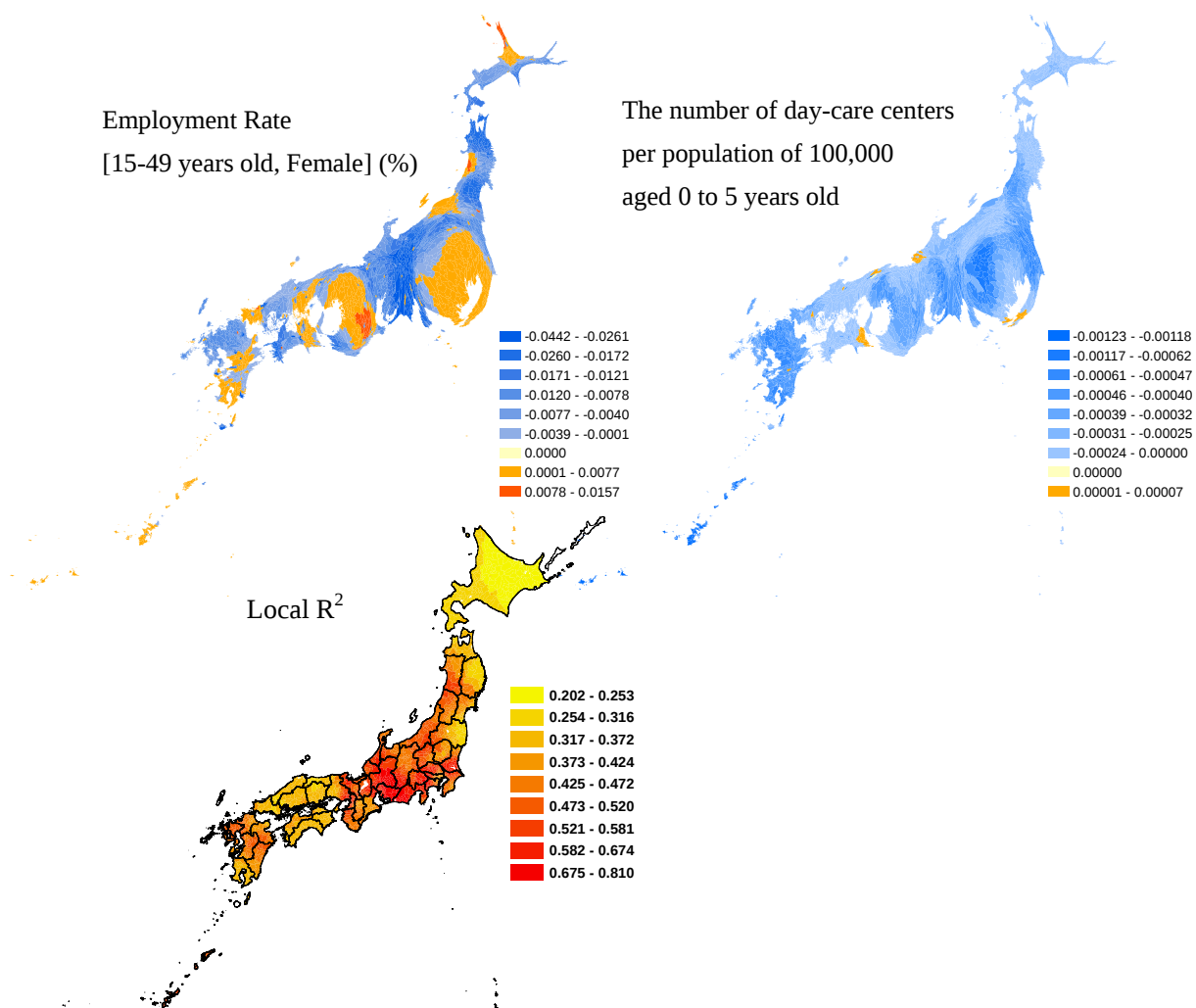


Figure 2 Distributions of Local Coefficients estimated by GWR and Local R^2