Spatiotemporal Analysis of Marriage and Marital Fertility in Japan: Using Geographically Weighted Regression 1980-2010

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Abstract (125)

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, each decade from 1980 to 2010. The analytical 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 result shows almost coefficients for covariates have statistically significant geographical variations. The coefficients by spatial areas are relatively stable at each period. The female labor force participation has a positive relationship with marital fertility in the urban areas.

Introduction

Regional patterns in Japanese fertility are characterized as "Low in the metropolitan areas, higher in 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 1.43 in 2013. 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**). 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), each decade from 1980 to 2010. 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**), almost coefficients for covariates have statistically significant geographical variations. The coefficients by spatial areas are relatively stable at each period. The female labor force participation and excess inbound rate have a positive relationship with marital fertility in the urban areas (**Figure 2-3**).

These results indicate that the 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	Source	Direction	Year	Min	25%	Mean	Median	75%	Max
Dependent Variable									
Standardized Marriage Ratio (SMR)※1	Census, Vital statistics		1980	1.040	1.399	1.435	1.443	1.482	1.656
			1990	0.907	1.281	1.315	1.323	1.364	1.529
			2000	0.738	1.155	1.193	1.203	1.249	1.512
			2010	0.550	0.991	1.036	1.041	1.091	1.294
Marital Fertility Ratio (MFRb)※1・2	Census, Vital statistics		1980	0.627	0.795	0.875	0.853	0.934	1.552
			1990	0.306	0.773	0.850	0.837	0.910	1.624
			2000	0.100	0.787	0.878	0.861	0.942	2.264
			2010	0.100	0.878	0.975	0.959	1.057	1.999
Independent Variable									
Proportion of Never-married Population [30-39 years old, Female] (%)	Census	-	1980	0.896	3.866	5.946	5.315	7.073	26.755
			1990	1.429	6.207	8.771	8.084	10.167	33.083
			2000	2.000	14.347	17.612	17.058	19.931	45.421
			2010	5.000	22.821	26.168	25.824	28.862	52.899
Proportion of Nuclear Family Household (%)	Census	-	1980	18.994	49.748	56.531	56.795	63.772	79.795
			1990	24.806	49.353	55.958	56.552	62.946	77.896
			2000	24.200	50.665	56.115	56.395	61.899	78.798
			2010	21.438	51.497	55.833	56.085	60.677	77.539
Excess Inbound Migrant Rate (%)	Census, Prefecture Report	+	1980	-0.076	-0.010	-0.001	-0.003	0.004	0.241
			1990	-0.170	-0.009	0.001	-0.003	0.007	0.130
			2000	-0.059	-0.008	-0.004	-0.004	0.000	0.054
			2010	-0.037	-0.006	-0.002	-0.003	0.001	0.070
Employment Rate [15-49 years old, Female] (%)	Census	+	1980	18.966	41.239	48.486	48.608	55.503	77.099
			1990	31.481	46.636	51.587	51.379	56.634	82.609
			2000	39.991	49.728	53.639	53.758	57.560	77.778
			2010	37.500	58.184	62.536	62.607	66.788	82.941
Male Unemployment rate (%)	Census	-	1980	0.000	1.636	2.606	2.230	3.090	20.468
			1990	0.000	2.135	3.167	2.802	3.722	17.913
			2000	0.000	3.504	4.641	4.525	5.414	21.021
			2010	0.000	6.070	7.652	7.362	8.848	28.956
Proportion of Foreign Population (%)	Census	+	1980	0.000	0.064	0.332	0.140	0.338	20.763
			1990	0.000	0.084	0.417	0.206	0.490	23.104
			2000	0.000	0.225	0.703	0.421	0.855	22.816
			2010	0.000	0.345	0.920	0.617	1.091	20.342
Sex Ratio for Never-married Population [20-34 years old]	Social Welfare Facility Survey	+	1980	62.50	142.97	172.17	163.19	186.18	1185.19
			1990	76.87	124.32	149.92	140.63	164.07	900.00
			2000	70.00	117.35	134.51	129.85	143.89	627.59
			2010	39.39	113.31	130.44	124.63	138.88	451.88

※1 Indirect standardized estimation method (Koike 2010) ※2 Number of birth is estimated by bayes methods using second medical areas.

Table 2 The descriptive statistics of the GWR results: summary

[SMR model]

Kernel function: Bi-square

Adaptive quantile	1980	0.03413753 (about 64 of 1901)
	1990	0.03786677 (about 71 of 1901)
	2000	0.03992211 (about 75 of 1901)
	2010	0.0452422 (about 86 of 1901)

Summary of GWR coefficient estimates:

Independent Variable	Model	Min.	25%	Median	75%	Max.	Global
Intercept	1980	-0.0515	1.0270	1.2950	1.4880	1.9710	1.3094
	1990	0.0043	0.8140	1.2520	1.4860	2.2240	1.2888
	2000	-0.4279	0.6101	0.9783	1.2940	2.3540	0.8859
	2010	-0.6454	0.4747	0.7651	1.0780	1.6600	0.5040
Proportion of Nuclear Family Household (%)	1980	-0.0071	-0.0006	0.0015	0.0049	0.0123	0.0014
	1990	-0.0072	-0.0013	0.0007	0.0048	0.0110	0.0000
	2000	-0.0067	-0.0004	0.0019	0.0066	0.0120	0.0024
	2010	-0.0064	0.0003	0.0033	0.0068	0.0121	0.0038
Excess Inbound Migrant Rate (%)	1980	-3.2740	0.3941	0.8841	1.6390	5.1710	0.8698
	1990	-1.3470	0.2414	0.8544	1.5650	4.4790	0.5044
	2000	-3.5480	-0.0620	0.8539	1.8500	5.9770	-0.0060
	2010	-5.0830	0.1098	1.4280	3.0730	6.6550	0.5638
Employment Rate [15-49 years old, Female] (%)	1980	-0.0131	-0.0016	0.0003	0.0020	0.0112	0.0006
	1990	-0.0122	-0.0027	-0.0004	0.0018	0.0102	0.0000
	2000	-0.0133	0.0029	-0.0002	0.0032	0.0148	0.0028
	2010	-0.0095	-0.0018	0.0002	0.0027	0.0146	0.0043
Male Unemployment rate (%)	1980	-0.1297	-0.0306	-0.0161	-0.0059	0.0511	-0.0149
	1990	-0.0645	-0.0216	-0.0144	0.0080	0.0337	-0.0140
	2000	-0.0745	-0.0278	-0.0177	-0.0112	0.0158	-0.0172
	2010	-0.0291	-0.0153	-0.0114	-0.0080	0.0080	-0.0094
Proportion of Foreign Population (%)	1980	-0.4030	-0.0572	-0.0206	0.0005	0.2485	-0.0208
	1990	0.2618	-0.0683	-0.0275	-0.0031	0.0905	-0.0230
	2000	-0.1792	-0.0250	-0.0024	0.0171	0.1309	-0.0172
	2010	-0.1297	-0.0107	-0.0009	0.0092	0.0922	-0.0046
Sex Ratio for Never-married Population [20-34 years old]	1980	-0.0007	0.0003	0.0006	0.0009	0.0025	0.0004
	1990	-0.0006	0.0004	0.0007	0.0012	0.0033	0.0005
	2000	-0.0006	0.0005	0.0009	0.0018	0.0044	0.0008
	2010	-0.0004	0.0006	0.0010	0.0016	0.0037	0.0010

Effective number of parameters: 568.1061 (1980), 518.0516 (1990), 505.8195 (2000), 457.2392 (2010)
Effective degree of freedom: 1332.894 (1980), 1382.948 (1990), 1395.181 (2000), 1443.761 (2010)
AIC:-7599.872 (1980), -7630.331 (1990), -7065.341 (2000), -6483.796 (2010), AICc: -6875.5(1980), -7002.1 (1990),
Quasi-global R^2: 0.851 (1980), 0.855 (1990), 0.842 (2000), 0.788 (2010)

[MFR model]

Kernel function: Bi-square

Adaptive quantile	1980	0.03944 (about 74 of 1901)
	1990	0.06152 (about 116 of 1901)
	2000	0.07208 (about 137 of 1901)
	2010	0.08527 (about 158 of 1853)

Summary of GWR coefficient estimates:

Independent Variable	Model	Min.	25%	Median	75%	Max.	Global
Intercept	1980	0.2149	0.7244	0.8582	1.0730	1.7810	0.8904
	1990	0.2963	0.6446	0.9228	1.2410	2.8300	0.8228
	2000	0.0963	0.7390	1.0070	1.2700	4.5620	0.9196
	2010	-1.0170	1.3240	1.6280	1.8480	2.9760	1.2047
Proportion of Never-married Population [30-39 years old, Female] (%)	1980	-0.0157	0.0025	0.0058	0.0092	0.0257	0.0041
	1990	-0.0417	-0.0084	-0.0041	0.0009	0.0793	-0.0023
	2000	-0.0543	-0.0106	-0.0059	-0.0040	0.0120	-0.0075
	2010	-0.0211	-0.0116	-0.0081	-0.0048	0.0166	-0.0058
Proportion of Nuclear Family Household (%)	1980	-0.0093	-0.0030	-0.0016	0.0000	0.0055	-0.0030
	1990	-0.0187	-0.0036	-0.0015	0.0005	0.0104	-0.0013
	2000	-0.0271	-0.0030	-0.0007	0.0013	0.0085	-0.0018
	2010	-0.0135	-0.0062	-0.0039	-0.0009	0.0235	-0.0013
Excess Inbound Migrant Rate (%)	1980	-7.7170	-1.4330	-0.6344	-0.2401	3.0100	0.6490
	1990	-7.7120	-1.3600	-0.3671	0.1567	5.2880	-0.9137
	2000	-8.2380	-2.2620	-0.4446	0.8731	14.2100	1.1957
	2010	-16.1500	-0.9811	1.7130	4.0180	16.3700	1.3297
Employment Rate [15-49 years old, Female] (%)	1980	-0.0093	-0.0020	0.0002	0.0025	0.0103	0.0015
	1990	-0.0300	-0.0033	0.0011	0.0050	0.0142	0.0018
	2000	-0.0350	-0.0032	-0.0004	0.0042	0.0155	0.0022
	2010	-0.0226	-0.0070	-0.0026	0.0009	0.0141	-0.0004
Male Unemployment rate (%)	1980	-0.1019	-0.0088	0.0036	0.0153	0.0859	0.0239
	1990	-0.1634	-0.0141	0.0002	0.0115	0.0537	0.0096
	2000	-0.0947	-0.0092	0.0062	0.0150	0.0578	0.0195
	2010	-0.0963	-0.0097	-0.0008	0.0050	0.0232	0.0057
Proportion of Foreign Population (%)	1980	-0.4597	-0.0244	-0.0002	0.0344	0.3733	-0.0271
	1990	-0.2381	-0.0059	0.0192	0.0752	0.5468	-0.0170
	2000	-0.2900	-0.0292	-0.0036	0.0098	0.1745	-0.0197
	2010	-0.1674	-0.0415	-0.0146	0.0012	0.1057	-0.0175

Effective number of parameters: 500.0544 (1980), 333.7106 (1990), 294.1553 (2000), 263.1271 (2010)
Effective degree of freedom: 1400.946 (1980), 1567.289 (1990), 1606.845 (2000), 1637.873 (2010)
AIC:-6266.942 (1980), -7630.331 (1990), -3028.979 (2000), -2143.191 (2010), AICc: --5673.1 (1980), -3322.423 (19
Quasi-global R^2: 0.871 (1980), 0.551 (1990), 0.583 (2000), 0.477 (2010)

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

[SMR model]

Leung et al. (2000)	year	F	d.f.1	d.f.2	SS OLS residuals	SS GWR residuals	SS GWR improvement
F(1) test	1980	0.3138 ***	1484.0	1894.0	7.315	1.616	
	1990	0.3245 ***	1523.1	1894.0	6.857	1.625	
	2000	0.3233 ***	1532.3	1894.0	9.235	2.200	
	2010	0.4518 ***	1568.1	1894.0	8.852	3.049	
F(2) test	1980	2.6300 ***	740.1	1894.0	7.315		5.699
	1990	2.8279 ***	680.5	1894.0	6.857		5.232
	2000	2.8927 ***	665.3	1894.0	9.235		7.036
	2010	2.7579 ***	603.7	1894.0	8.852		5.804
F(3) test		F (1980)	Numerator d.f.(1980)	Dominator d.f. (1980)	F (1990)	Numerator d.f. (1990)	Dominator d.f. (1990)
Intercept		3.7847 ***	660.7	1484.0	6.4596 ***	658.4	1523.1
Proportion of Nuclear Family Household (%)		5.8516 ***	642.9	1484.0	9.9443 ***	640.6	1523.1
Excess Inbound Migrant Rate (%)		3.2484 ***	401.7	1484.0	3.3944 ***	411.7	1523.1
Employment Rate [15-49 years old, Female] (%)		3.4035 ***	687.6	1484.0	3.2121 ***	607.2	1523.1
Male Unemployment rate (%)		3.9798 ***	438.3	1484.0	1.8641 ***	422.5	1523.1
Proportion of Foreign Population (%)		2.0530 ***	239.3	1484.0	2.1612 ***	204.0	1523.1
Sex Ratio for Never-married Population [20-34 years old]		5.4333 ***	434.4	1484.0	9.5507 ***	389.1	1523.1
F(3) test		F (2000)	Numerator d.f. (2000)	Dominator d.f. (2000)	F (2010)	Numerator d.f. (2010)	Dominator d.f. (2010)
Intercept		4.7335 ***	610.3	1532.3	4.7765 ***	579.9	1568.1
Proportion of Nuclear Family Household (%)		8.5196 ***	632.0	1532.3	7.2969 ***	571.1	1568.1
Excess Inbound Migrant Rate (%)		2.2403 ***	468.5	1532.3	2.2576 ***	449.9	1568.1
Employment Rate [15-49 years old, Female] (%)		3.0553 ***	586.8	1532.3	3.1444 ***	594.3	1568.1
Male Unemployment rate (%)		2.7259 ***	446.7	1532.3	1.7781 ***	466.3	1568.1
Proportion of Foreign Population (%)		2.6493 ***	198.1	1532.3	2.4507 ***	193.2	1568.1
Sex Ratio for Never-married Population [20-34 years old]		6.9332 ***	375.6	1532.3	4.0715 ***	330.6	1568.1

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

[MFR model]

Leung et al. (2000)	year	F	d.f.1	d.f.2	SS OLS residuals	SS GWR residuals	SS GWR improvement
F(1) test	1980	0.2266 ***	1536.6	1894.0	20.022	3.356	
	1990	0.5874 ***	1660.6	1894.0	29.139	14.163	
	2000	0.5459 ***	1689.8	1894.0	43.386	20.094	
	2010	0.6303 ***	1712.4	1894.0	59.484	32.422	
F(2) test	1980	3.1975 ***	658.1	1894.0	20.022		16.666
	1990	2.9795 ***	447.3	1894.0	29.139		14.976
	2000	3.5409 ***	396.0	1894.0	43.386		23.292
	2010	3.3643 ***	355.0	1894.0	59.484		27.062
F(3) test		F (1980)	Numerator d.f.(1980)	Dominator d.f. (1980)	F (1990)	Numerator d.f. (1990)	Dominator d.f. (1990)
Intercept		1.9580 ***	608.6	1536.6	2.1650 ***	534.7	1660.6
Proportion of Never-married Population [30-39 years old, Female] (%)		1.5273 ***	522.0	1536.6	2.4318 ***	479.4	1660.6
Proportion of Nuclear Family Household (%)		1.4879 ***	605.2	1536.6	1.5225 ***	475.9	1660.6
Excess Inbound Migrant Rate (%)		2.5257 ***	401.9	1536.6	2.5950 ***	375.6	1660.6
Employment Rate [15-49 years old, Female] (%)		2.2129 ***	650.0	1536.6	2.3073 ***	580.6	1660.6
Male Unemployment rate (%)		2.4141 ***	377.8	1536.6	3.0773 ***	347.2	1660.6
Proportion of Foreign Population (%)		1.1705	200.2	1536.6	1.4207 **	137.9	1660.6
F(3) test		F (2000)	Numerator d.f. (2000)	Dominator d.f. (2000)	F (2010)	Numerator d.f. (2010)	Dominator d.f. (2010)
Intercept		2.3944 ***	513.3	1689.8	1.2427 ***	579.3	1712.4
Proportion of Never-married Population [30-39 years old, Female] (%)		2.6300 ***	503.8	1689.8	1.7548 ***	533.9	1712.4
Proportion of Nuclear Family Household (%)		2.0474 ***	578.7	1689.8	2.8067 ***	561.2	1712.4
Excess Inbound Migrant Rate (%)		2.8475 ***	401.3	1689.8	3.3202 ***	327.9	1712.4
Employment Rate [15-49 years old, Female] (%)		1.5758 ***	495.6	1689.8	1.5482 ***	563.0	1712.4
Male Unemployment rate (%)		1.9795 ***	406.1	1689.8	1.9299 ***	403.4	1712.4
Proportion of Foreign Population (%)		1.6569 ***	136.0	1689.8	1.5104 ***	130.9	1712.4

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

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

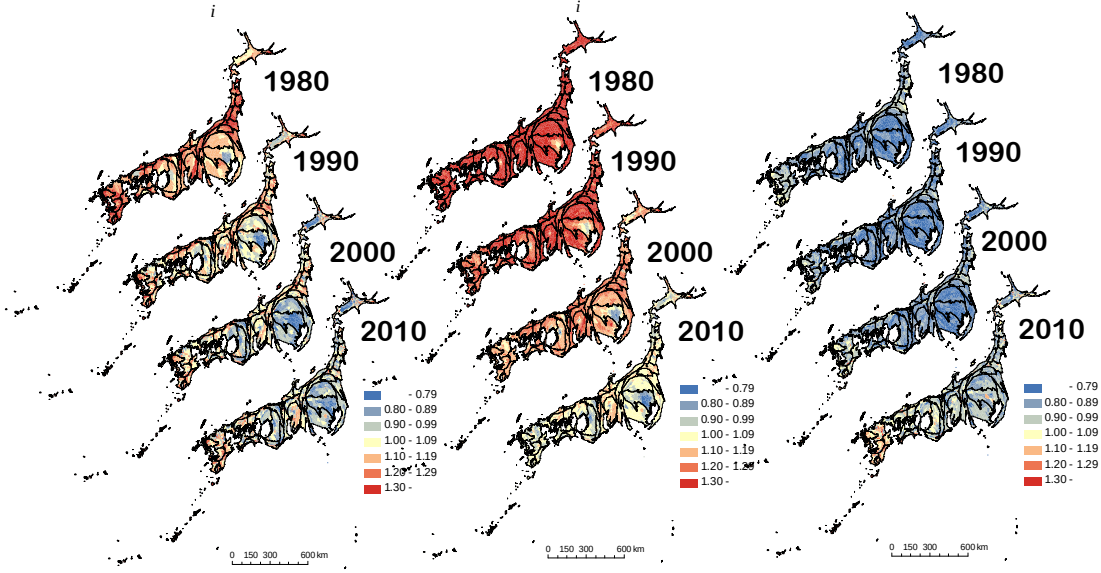

Figure 1 Distribution of SFR, SMR and MFR: 1980 - 2010

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

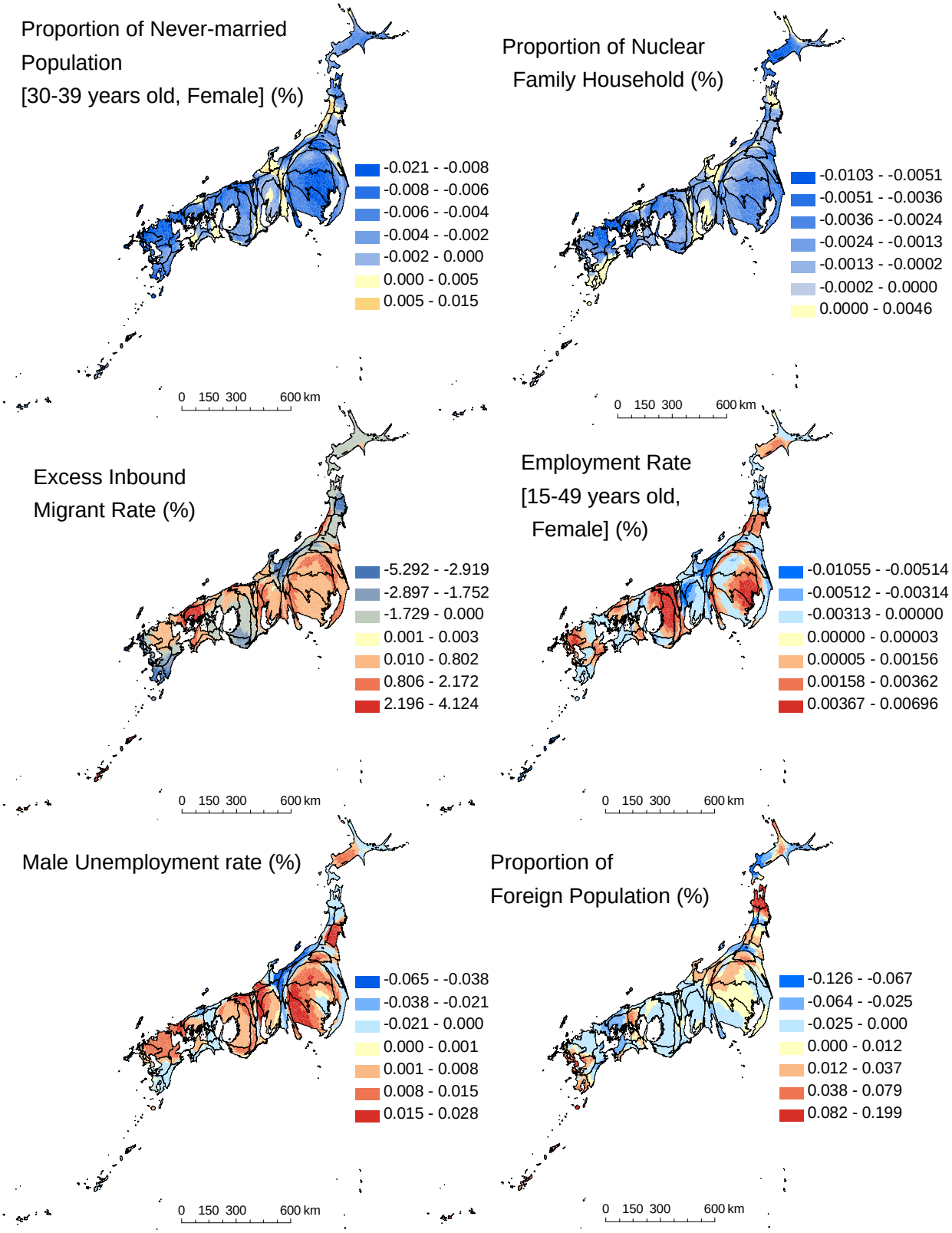

Figure 3 Distribution of average GWR coefficients [SMR model]: 1980 - 2010

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

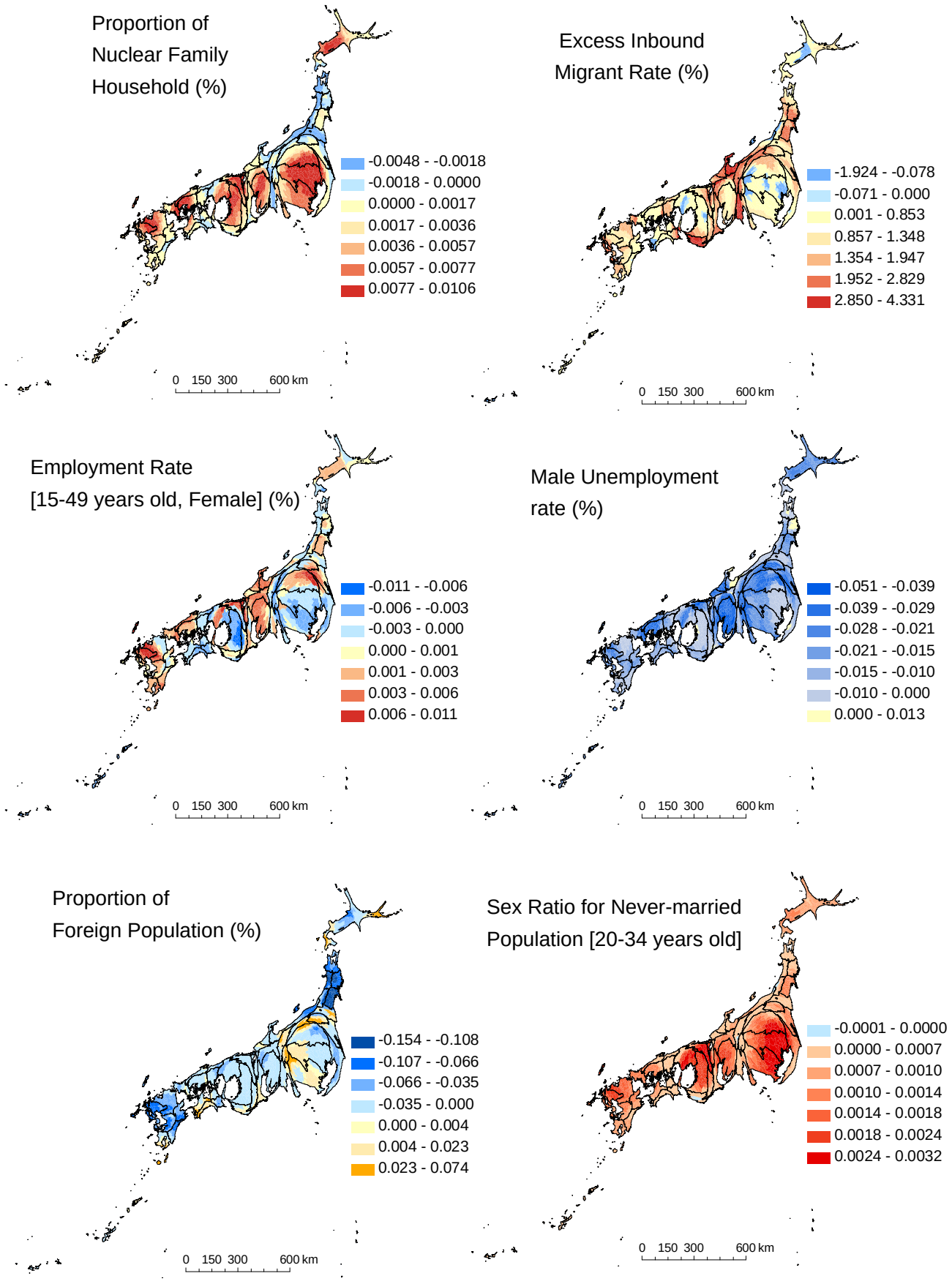

Figure 3 Distribution of average GWR coefficients [MFR model]: 1980 - 2010

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