Diffusion Process of Fertility Transition in Japan
Regional Analysis using Spatial Panel Econometric Model

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Abstract

This study aims to verify the diffusion process of fertility transition in Japan. I analyzed the Japanese regional fertility using spatial panel econometric models (Spatial Lag and Spatial Durbin model) to verify diffusion process between regions. The working hypothesis is which effects of adaptation or diffusion are influence the fertility decline, or the effects of both are detected?

The sample is 47 prefectures, and the observed periods are from 1920 to 2010 (every 5 years, it is excluded in 1945). The dependent variable is the standardized marital fertility ratio (MFR). The standard population is 1930. Independent variables are (a) female mean age at first marriage, (b) infant mortality, and (c) proportion of primary industries. Covariate variables are population density (per km^2), the sex ratio of total population, and the train time to nearest mega city.

As a result of the analyses, for hypothesis, the effect of both the adaptation process and the diffusion process was confirmed. It hopes to continue model estimation and that separated the time in the future, such as the possibility of different covariates in each period, the study centered on deepening of the model.

Introduction

According to the Princeton European Project, the classic mechanism of fertility transition can be attributed to the diffusion of ideas and behaviors related to birth control to share the same language, ethnicity, and religion rather than the adaptation process to the socio-economic structure (Coale and Watkins 1979, 1986, Watkins 1987, knodel and van de Walle 1979, Bongaats and Watkins 1996). However, in recent years, some studies have been made using a spatial econometric models, from the adaptive or diffusion or such dichotomy problem setting, both effects are detected (Montgomery and Casterlin 1993, Casterline 2001, Palloni 2001, Goldstein and Klüsener 2014, Vitali and Billari 2014). Clerand (2001) called such a both effects as the “Blended model”.

Japan is a county in lowest-low fertility. Regional patterns in Japanese fertility are characterized as "Low in the metropolitan areas, higher in non-metropolitan areas" trends came to be observed from 1920 to 2010. 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 1.42 in 2014.

This study analyze the fertility transition in Japan using the spatial panel econometric models. The analytical unit is prefecture level. The working hypothesis is which effects of adaptation or diffusion are influence the fertility decline, or the effects of both are detected?

Data and Method

The sample is 47 prefectures, and the observed periods are from 1920 to 2010 (every 5 years, it is excluded in 1945 because of WWII, Figure 1 and 2). The dependent variable is the standardized marital fertility ratio (MFR). The standard population is 1930 to calculate standardized indices.

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

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

Independent variables are (a) female mean age at first marriage, (b) infant mortality, and (c) proportion of primary industries. Covariate variables are population density (per km^2), the sex ratio of total population, and the train time to nearest mega city. Descriptive statistics of variables are shown in Table 1.

To verify the hypothesis, I use the spatial panel modeling, the spatial lag model and the spatial durbin model (LeSage and Pace 2009). The former model is that dependent variable is influenced by the weighted average Y of neighboring prefectures, the latter model is that dependent variable is influenced by the weighted average Y and X of neighboring prefectures.

Spatial lag model : $Y=\rho WY + X\beta+\varepsilon$
Spatial Durbin model : $Y=\rho WY + X\beta+ WX\gamma+\varepsilon$

ρ : spatial parameter of Y, W: row standardized mean weight assigned from neighboring prefectures
γ: spatial parameter of X

These model are that the estimation of the diffusion effect, creating spatial weighting matrix between the prefectures (queen type of lag 1), if there is an interaction effect with the fertility of the weighting area, diffusion effect can be confirmed.

Results

Table 2 represents the results of spatial lag model, and Table 3 represents the results of spatial Durbin model. As results of the analyses, for hypothesis, the effect of both the adaptation process and the diffusion process were confirmed. The adaptation process is verified by significant coefficients of (a) female mean age at first marriage, (b) infant mortality, and (c) proportion of primary industries, and the diffusion process is verified by significant coefficients of spatial parameters ρ and γ.

It hopes to continue model estimation and that separated the time in the future, such as the possibility of different covariates in each period, the study centered on deepening of the model.

References

- Bongaarts, J. and Watkins, S.C., 1996. "Social interactions and Contemporary Fertility Transitions", *Population and Development Review*, 22(4), pp.639–682.
- Carlsson, G., 1966. "The Decline of Fertility: Innovation or Adjustment Process", *Population Studies*, Vol. 20, No. 2 (November), pp. 149-174.
- Casterline, J. B., 2001. "Diffusion Processes and Fertility Transition: Introduction", Casterline, J. (ed.), *Diffusion Processes and Fertility Transition: Selected Perspectives*. Washington, D.C.: The National Academies Press, pp.1–38.
- Cleland, J., 2001. "Potatoes and Pills: An Overview of Innovation-Diffusion Contributions to Explanations of Fertility Decline", Casterline, J. (ed.), *Diffusion Processes and Fertility Transition: Selected Perspectives*. Washington, D.C.: The National Academies Press, pp.39–65.
- Coale, A.J., 1973. "The demographic transition reconsidered", in International Union for the Scientific Study of Population IUSSP, Proceedings of the International Population Conference 1973. Liège: Editions Ordina. Volume 1, 53–73.
- Coale, A. J. and S. C. Watkins, 1979. "The Decline of Fertility in Europe since the Eighteenth Century as a Chapter in Human Demographic History". *The Decline of Fertility in Europe –The Revised Proceedings of a Conference on the Princeton European Fertility Project-*, Princeton, 1986. Princeton University Press.
- Coale, A.J. and Watkins, S.C., 1986. *The Decline of Fertility in Europe*. Princeton: Princeton University Press.
- Goldstein J. R. and Klüsener, 2014. "Spatial Analysis of the Causes of Fertility Decline in Prussia", *Population and Development Review*, Volume 40, Issue 3, pages 497–525.
- Knodel, J. and van de Walle, E., 1979. "Lessons from the past: Policy implications of historical fertility studies", *Population and Development Review*, 5(2), pp.217–245.
- LeSage, J. and R. K. Pace, 2009. *Introduction to Spatial Econometrics*, CRC Press
- Montgomery, M. R. and J. B. Casterlin, 1993. "The Diffusion of Fertility Control in Taiwan: Evidence from Pooled Cross-Section Time-Series Models", *Population Studies*, Vol.47, No.3 (Nov.,1993), pp.457-479.
- Montgomery, M. R. and J. B. Casterlin, 1993. "The Diffusion of Fertility Control in Taiwan: Evidence from Pooled Cross-Section Time-Series Models", Population Studies, Vol.47, No.3 (Nov.,1993), pp.457-479.
- Vitali, A. and F. Billari, 2014. "Changing determinants of low fertility and diffusion: A spatial analysis for Italy", ESRC Centre for population change, Working Paper 57.
- Watkins, S.C., 1987. "The fertility transition: Europe and the third world compared", *Sociological Forum*, 2(4), pp.645–75.

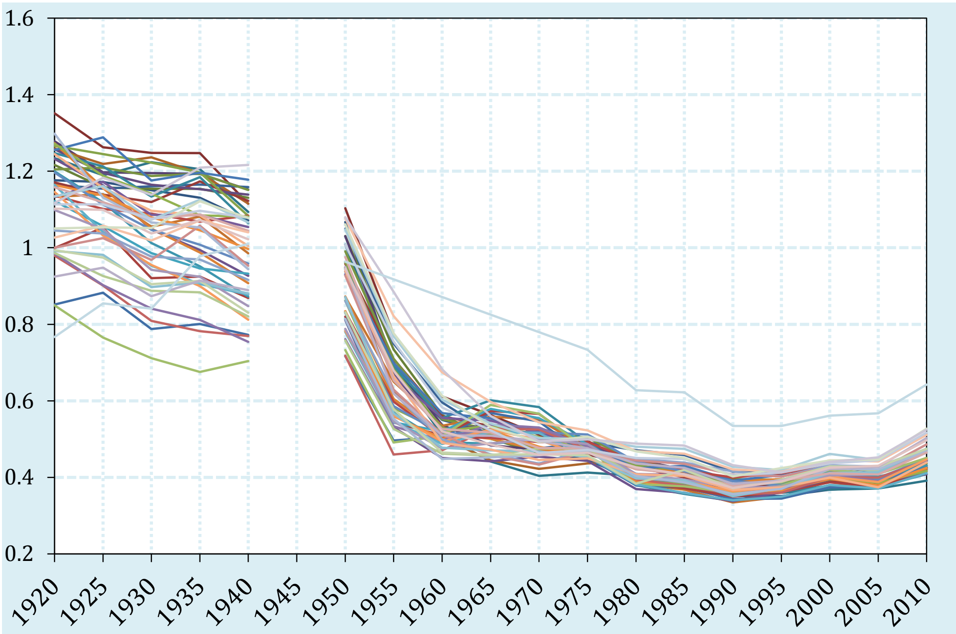

Figure 1 MFR by prefecture: 1920-2010

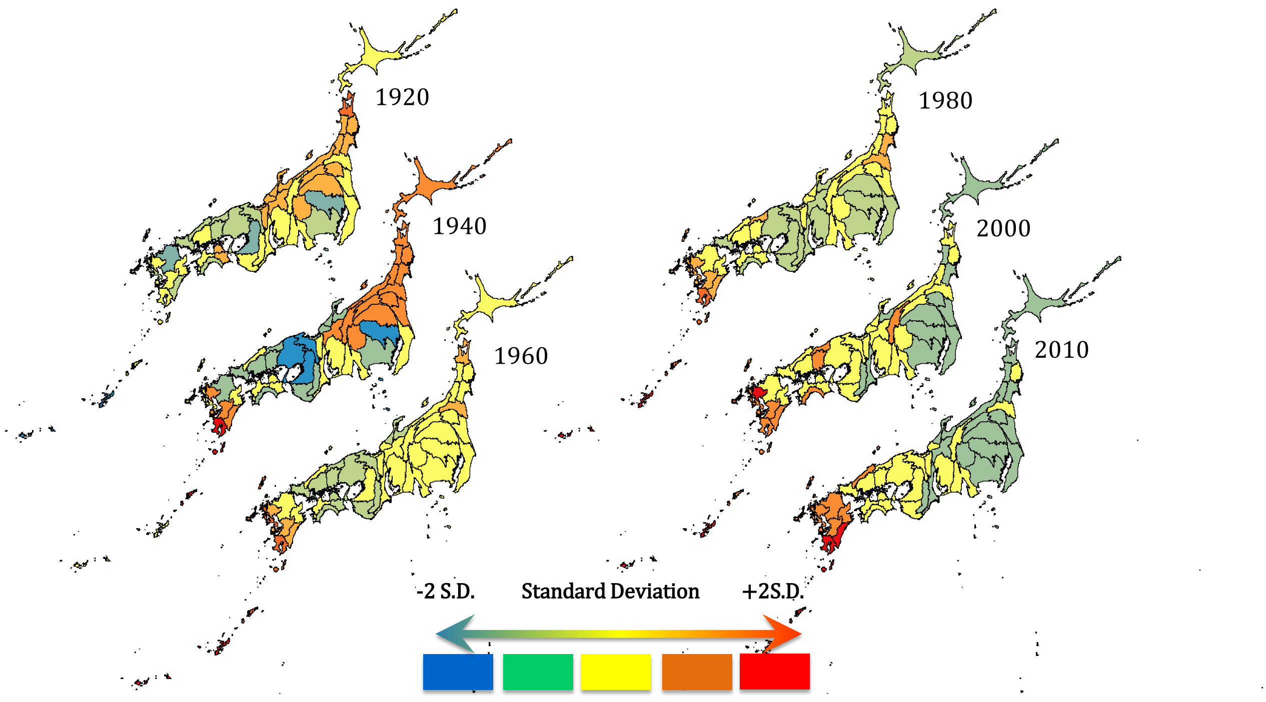

Figure 2 Geographical Distribution of MFR: 1920, 40, 60, 80, 2000, 10

* The Cartogram (based on Total Population 2010) is created using the Gastner-Newman method in ArcGIS.

Table 1 Descriptive Statistics

Variables		Mean	S.D.	Min.	Max	N	
Standardised Marital Fertility Ratio: MFR	Total	0.653	0.291	0.335	1.352	N =	846
	between		0.049	0.547	0.757	n =	47
	within		0.287	0.292	1.311	T =	18
Population Density (per km2)	Total	5.592	0.883	3.340	8.701	N =	846
	between		0.851	3.971	8.305	n =	47
	within		0.263	4.461	6.384	T =	18
Female First Marriage Age	Total	24.809	2.576	18.690	30.790	N =	846
	between		0.545	23.797	26.291	n =	47
	within		2.519	19.600	30.552	T =	18
Infant Mortality	Total	47.127	54.778	1.052	223.805	N =	846
	between		7.025	28.483	64.178	n =	47
	within		54.335	-14.888	220.884	T =	18
Propotion of Primary Industries	Total	31.632	22.872	0.400	75.400	N =	846
	between		9.039	5.292	44.874	n =	47
	within		21.049	-3.622	86.296	T =	18
Sex Ratio of Total Population	Total	95.349	4.332	86.300	113.800	N =	846
	between		2.968	90.139	104.833	n =	47
	within		3.184	85.415	107.315	T =	18
Train Time to Nearest Mega City Area	Total	5.111	1.937	0.000	8.994	N =	846
	between		1.904	0.648	8.460	n =	47
	within		0.447	4.049	6.052	T =	18

Table 2 Results of Spatial Lag Model for MFR

	Spatial Lag Model					
Dependent Variable:	(1)		(2)		(3)	
Standardised Marital Fertility Ratio	Fixed Effect		Fixed Effect		Fixed Effect	
	β		β		β	
Piecewise Linear Spline Function						
Year 1920-1950	0.05147	**	0.01561	+	0.03667	**
Year 1950-1960	0.07372	**	0.02964	*	0.07785	**
Year 1960-1975	-0.01105	+	-0.01100		0.03542	**
Year 1975-2005	0.04801	**	-0.00232		0.01177	**
Year 2005-2010	-0.04408	+	-0.05679		-0.05048	*
Population Density (per km2)	0.00663		-0.00351		-0.07054	*
Female Mean Age at First Marriage	-0.07423	**				
Infant Mortality			-0.00013			
Propotion of Primary Industries					0.00556	**
Sex Ratio of Total Population	0.01118	**	0.01731	**	0.02413	**
Train Time to Nearest Mega City Area	-0.11362	**	-0.12907	**	-0.09926	**
Constant						
Spatial Parameter						
ρ(Spatila Lag of neighbors of Y)	0.30043	**	0.30041	**	0.30021	**
N	846		846		846	
Group N	47		47		47	
Period	18		18		18	
Standard Error of model	0.014	**	0.015	**	0.014	**
Log Likelihood	401.8		379.2		396.2	
AIC	-781.7		-736.3		-770.3	
BIC	-729.5		-684.2		-718.2	

Significant Levels: ** <0.01, * <0.05, + < 0.10

Table 3 Results of Spatial Durbin Model for MFR

Dependent Variable: Standardised Marital Fertility Ratio	Spatial Durbin Model (4f) Fixed Effect β	(4r) Random Effect β	(5f) Fixed Effect β	(5r) Random Effect β	(6f) Fixed Effect β	(6r) Random Effect β
Piecewise Linear Spline Function						
Year 1920-1950	-0.00166	0.00183	-0.03151 **	-0.02966 **	0.01295 **	0.01307 **
Year 1950-1960	0.01560 +	0.01931 *	-0.01041	-0.00904	-0.00817	-0.00856
Year 1960-1975	-0.00070	-0.00096	-0.01740 **	-0.01589 **	-0.05044 **	-0.05086 **
Year 1975-2005	-0.01514 *	-0.01112 +	-0.00243	-0.00149	-0.00940 **	-0.00952 **
Year 2005-2010	-0.03134 +	-0.03033 +	-0.02289 +	-0.01519	0.01802	0.01718
Population Density (per km2)	0.05032 *	0.04690 *	0.04947 **	0.04126 **	0.02199	0.01544
Female Mean Age at First Marriage	-0.07237 **	-0.07331 **				
Infant Mortality			0.00308 **	0.00314 **		
Propotion of Primary Industries					0.00613 **	0.00626 **
Sex Ratio of Total Population	0.00422 **	0.00451 **	0.00401 **	0.00395 **	0.00682 **	0.00669 **
Train Time to Nearest Mega City Area	-0.05465 **	-0.05418 **	-0.04467 **	-0.02738 **	0.02015 +	0.01877 *
Constant		-0.87611 *		-0.27585 *		-0.66895 **
Spatial Parameter						
ρ(Spatila Lag of neighbors of Y)	0.30149 **	0.30137 **	0.30418 **	0.30410 **	0.30282 **	0.30269 **
θ (Spatila Lag of neighbors of X)		-3.99735 **		-2.70422 **		-2.16644 **
Wx						
Female Mean Age at First Marriage	0.02437 **	0.02311 **				
Infant Mortality			-0.00134 **	-0.00136 **		
Propotion of Primary Industries					-0.00341 **	-0.00346 **
N	846	846	846	846	846	846
Group N	47	47	47	47	47	47
Period	18	18	18	18	18	18
Standard Error of model	0.008 **	0.008 **	0.004 **	0.004 **	0.005 **	0.005 **
Log Likelihood	663.9	450.0	965.4	809.0	884.4	752.9
AIC	-1303.9	-872.1	-1906.8	-1590.0	-1744.8	-1477.8
BIC	-1247.0	-805.7	-1849.9	-1523.6	-1687.9	-1411.4
Hausman Test		-17.5		92.8 **		-10.1

Significant Levels: ** <0.01, * <0.05, + < 0.10