APPENDIX

Federal Subjects of the Russian Federation:

1. Altay Krai
2. Amur Oblast
3. Arkhangelsk Oblast
4. Astrakhan Oblast
5. Belgorod Oblast
6. Bryansk Oblast
7. Vladimir Oblast
8. Volgograd Oblast
9. Vologda Oblast
10. Voronezh Oblast
11. Jewish Autonomous Oblast
12. Zabaikalsky Krai
13. Ivanovo Oblast
14. Irkutsk Oblast
15. Kaliningrad Oblast
16. Kaluga Oblast
17. Kamchatka Krai
18. Kemerovo Oblast
19. Kirov Oblast
20. Kostroma Oblast
21. Krasnodar Krai
22. Krasnoyarsk Krai
23. Kurgan Oblast
24. Kursk Oblast
25. Leningrad Oblast
26. St. Petersburg
27. Lipetsk Oblast
28. Magadan Oblast
29. Moscow Oblast
30. Moscow
31. Murmansk Oblast
32. Nenets Autonomous Okrug
33. Nizhny Novgorod Oblast
34. Novgorod Oblast
35. Novosibirsk Oblast
36. Omsk Oblast
37. Orenburg Oblast
38. Oryol Oblast
39. Penza Oblast
40. Perm Krai
41. Primorsky Krai
42. Pskov Oblast
43. Republic of Adygeya
44. Republic of Altai
45. Republic of Bashkortostan
46. Republic of Buryatia
47. Republic of Dagestan
48. Republic of Ingushetia
49. Republic of Kabardino-Balkaria
50. Republic of Kalmykia
51. Republic of Karachay-Cherkessia
52. Republic of Karelia
53. Republic of Komi
54. Republic of Crimea
55. Sevastopol
56. Republic of Mari El
57. Republic of Mordovia
58. Republic of Sakha (Yakutia)
59. Republic of North Ossetia - Alania
60. Republic of Tatarstan
61. Republic of Tyva
62. Republic of Udmurtia
63. Republic of Khakassia
64. Chechen Republic
65. Republic of Chuvashia
66. Rostov Oblast
67. Ryazan Oblast
68. Samara Oblast
69. Saratov Oblast
70. Sakhalin Oblast
71. Sverdlovsk Oblast
72. Smolensk Oblast
73. Stavropol Krai
74. Tambov Oblast
75. Tver Oblast
76. Tomsk Oblast
77. Tula Oblast
78. Tyumen Oblast
79. Ulyanovsk Oblast
80. Khabarovsk Krai
81. Khanty-Mansi Autonomous Okrug - Yugra
82. Chelyabinsk Oblast
83. Chukotka Autonomous Okrug
84. Yamal-Nenets Autonomous Okrug
85. Yaroslavl Oblast

Figure 1S. Federal subjects of the Russian Federation. Due to data limitation we did not include Crimea Republic (54) and Sevastopol (55) in this study.
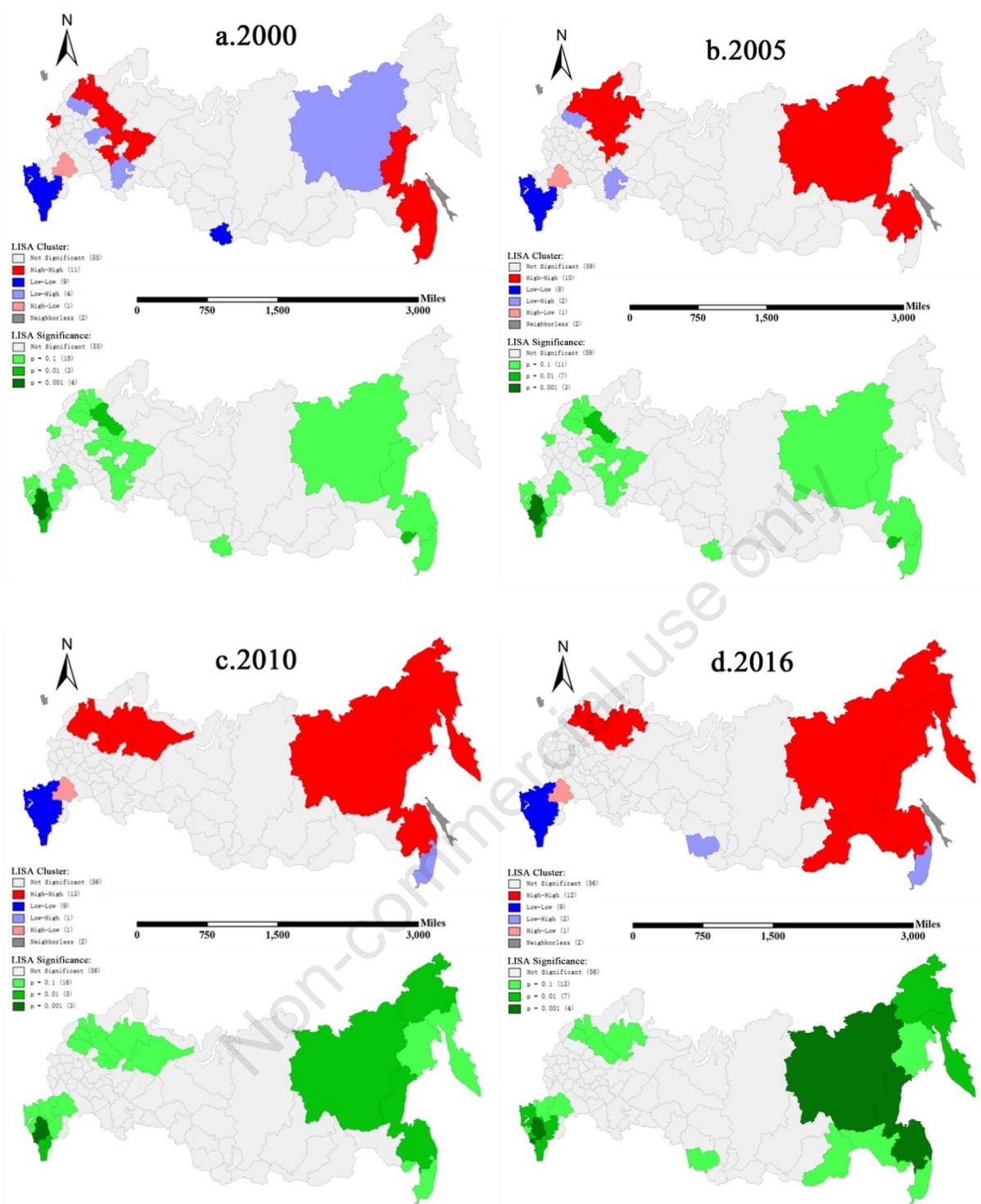
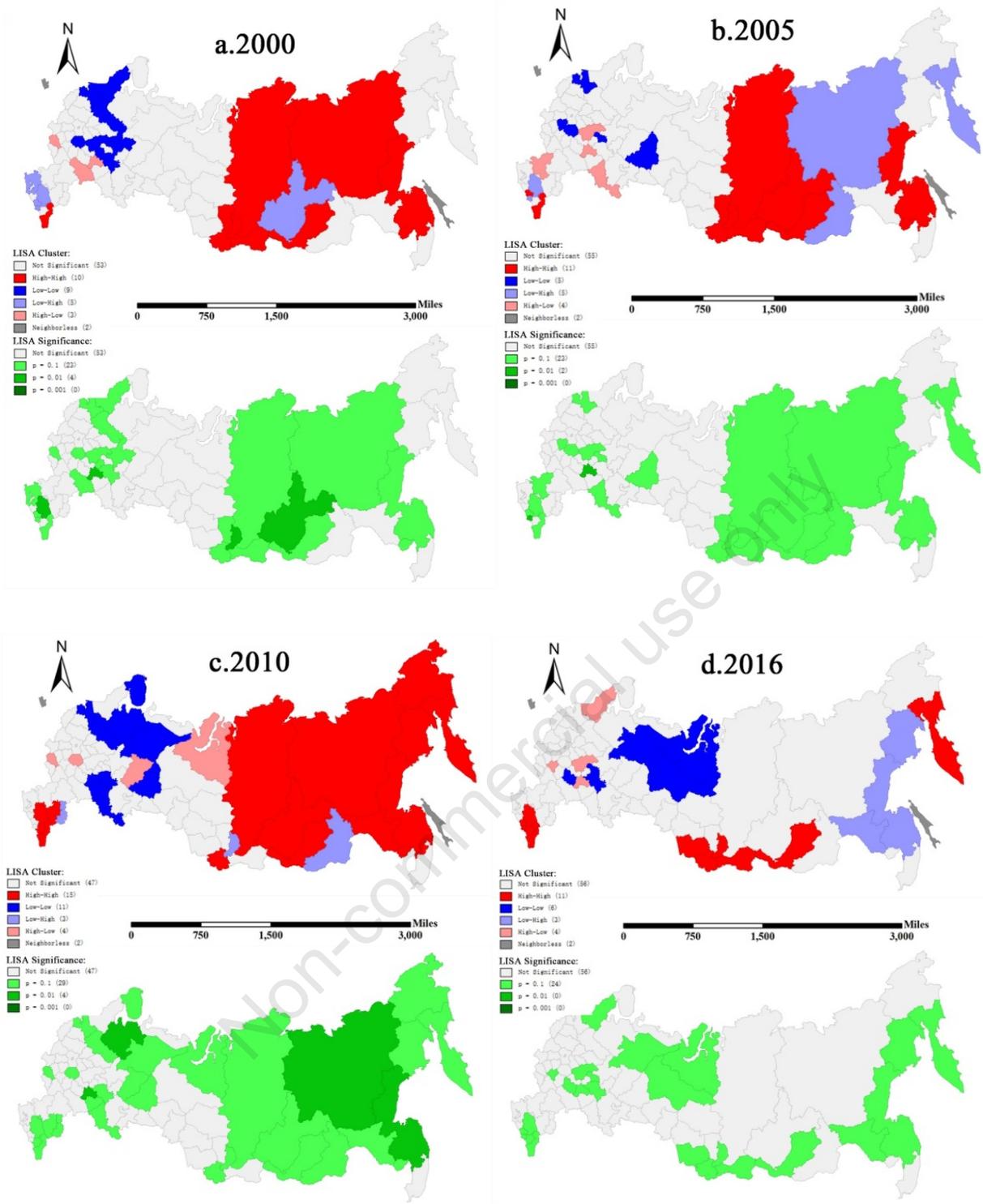**Figure S2. Spatial aggregation of the abortion rate in Russia. Spatial aggregation by LISA.**

Figure S3. Spatial Aggregation of infant mortality rate in Russia. Spatial aggregation by LISA.

Table S1. Covariates included in the study (n=83).

Covariates	Year	Maximum	Minimum	Mean	SD
Unemployment rate (%)	2000	32.00	3.80	11.92	4.67
	2004	46.30	1.60	9.46	5.97
	2010	51.80	2.15	9.18	5.65
	2017	26.80	1.30	6.20	3.47
GRP (per capita USD)	2000	63,870	1,795	6,980	8,869
	2004	77,537	1,360	9,928	12,368
	2009	164,931	3,494	18,452	21,189
	2015	227,793	5,085	21,817	30,365
Life expectancy (years)	2000	74.00	56.10	65.21	2.29
	2005	75.64	56.01	64.47	3.20
	2009	78.31	58.22	67.85	2.73
	2016	80.82	64.21	71.15	2.42
Total population (x 1,000)	2000	9933.00	41.50	1801.13	1580.38
	2005	10726.00	41.80	1764.44	1628.00
	2010	11382.00	42.10	1752.20	1690.33
	2017	12381.00	43.80	1771.80	1804.34
Urbanization rate (%)	2000	100	25.7	69.4	12.9
	2005	100	26.1	69.5	12.7
	2010	100	27.3	69.8	12.7
	2017	100	29.0	70.8	12.6
Education index	1999	0.99	0.80	0.90	0.02
	2004	1.00	0.78	0.90	0.03
	2010	0.98	0.82	0.91	0.03
	2015	1.00	0.84	0.94	0.03

Tables S2-S5

Simple OLS technique run on Panel data, with space fixed, time fixed and also space and time fixed (Table S2). In the model with both time and space fixed, LM_{lag} significantly (p=1%, 5%) rejects the hypothesis of no spatial effect of the variables on the AR indicating spatial effect should be included. R_LM_{lag} and R_LM_{error} significantly rejected the hypothesis indicating the necessity to use the SDM model and conduct the Wald and LR tests know if SDM can be simplified into SLM or SEM. However, in the space-time fixed model, none of the four parameters (LM_{lag}, R_LM_{lag}, LM_{error} and R_LM_{error}) passed the significance test, which allowed us to accept the hypothesis. Thus, it was then necessary to combine the LR space and time test together to find out which fixed model to choose.

Table S2. Panel data model estimation results without spatial interaction.

Parameter	OLS	Space-fixed effects	Time-fixed effects	Space and time-fixed effects
R2	0.5953	0.7354	0.3274	0.1100
σ2	9.7245	4.6138	6.5641	2.8873
LM_{lag}	72.7124***	102.8390***	7.0849***	0.2930
R_LM_{lag}	23.6287***	57.8596***	21.7737***	0.0046
LM_{error}	54.4349***	49.2111***	0.3604	0.3378
R_LM_{error}	5.3512**	4.2317**	15.0492***	0.0495

***,** and * indicate significance at the confidence levels of 1%, 5% and 10%, respectively.

Through the LR test (table S3), the *p*-values from both space fixed effects and the time fixed effects are significant (*p*< 0.001), rejected the null hypothesis of no space fixed effect and no time effect. The next step is thus to include both time effect and space effect in the space panel model.

Table S3. Panel data model LR test results.

Effect	LR value	Degree of freedom	*p*-value
LR-test joint significance spatial fixed effects	269.3866	82	<0.001
LR-test joint significance time- fixed effects	240.7444	4	<0.001

In the three differently fixed models, both the LR and Wald test reject SDM to be simplified into SEM or SLM at the 5% significance level, therefore it is necessary to conduct space-fixed SLM, SEM and SDM, and time-fixed SLM and SDM, compare the result and select the best-fit model.

Table S4. SDM model Wald test and LR test results.

Spatial parameter	Space-fixed effects	Time-fixed effects	Space and time-fixed effects
Wald spatial lag	49.0828***	18.4655***	18.2740***
Wald spatial error	67.6323***	21.9687***	18.0043***
LR spatial lag	46.5962***	16.1595**	16.8700***
LR spatial error	76.9187***	20.6589***	16.5431**

***,** and * indicate significance at the confidence levels of 1%, 5% and 10%, respectively.

The significance of the estimation coefficients of the explanatory variables, the Corrected R2, and Log-Likelihood in table S5, led to the space-fixed SDM model to be chosen as the best-fit model.

Table S5. Estimation results of panel model with different specific effects.

Model / Variable	Time-fixed effects SLM	Space-fixed effects SLM	Space-fixed effects SEM	Time-fixed effects SDM	Spece-fixed effects SDM
Unemployment_rate	0.249484***	0.099315**	0.03723	0.234366***	0.067345
GRP	-0.000001	-0.00007***	-0.000065***	-0.000003	-0.000071***
Education_index	-14.876256**	10.749531	-12.114067	-16.954466***	6.726972
Urbanization_rate	-0.041683***	0.03259	0.10286	-0.036137***	0.082401
Life_expectancy	-0.425924***	-0.409955***	-0.723008***	-0.441705***	-0.433857***
Total_population	0.000118	0.003839***	0.003082***	0.000176*	0.003394***
W*Unemployment_rate				0.203535***	0.392554***
W*GRP				0.000003	-0.000021
W*Education_index				4.560394	42.203621***
W*Urbanization_rate				0.0108	-0.493688**
W*Life_expectancy				-0.093455	0.042921
W*Total population			(SEM)spat.aut.:	-0.000251	0.003261*
W*dep.var.	0.091983	0.524996***	0.621532***	-0.012995	0.372977***
σ^2	6.3719	4.1117	5.5982	6.0396	3.701
R^2	0.729	0.8251	0.6968	0.7431	0.8426
Corrected R^2	0.3381	0.6945	0.6063	0.3689	0.7632
LogL	-768.52807	-708.66957	-723.83125	-760.44833	-685.3715

***,** and * indicate significance at the confidence levels of 1%, 5% and 10%, respectively.

Table S6-S9

Simple OLS technique run on Panel data, with space-fixed, time fixed and also space and time fixed (Table S6). In the time-fixed and space-fixed models, LM_{lag} significantly (p=1%, 5%) rejects the hypothesis of no spatial effect of the variables on the infant mortality rate (IMR), which indicates that spatial effects should be included. R_LM_{lag} and R_LM_{error} significantly rejected the hypothesis indicating the necessity to use the SDM model and conduct the Wald and LR tests to find out if SDM can be simplified into SLM or SEM. However, in the space-time fixed model, none of the four parameters (LM_{lag}, R_LM_{lag}, LM_{error} and R_LM_{error}) passed the significance test, which allowed us to accept the hypothesis. Thus, it was necessary to combine LR the test of space and time together to see which fixed model to choose.

Table S6. Panel data model estimation results without spatial interaction.

Parameter	OLS	Space-fixed effects	Time-fixed effects	Space and time-fixed effects
R2	0.5953	0.7354	0.2336	0.1316
σ2	9.7245	4.6138	7.4789	2.8173
LMlag	28.1235***	27.1829***	6.6841**	0.6644
R_LMlag	20.0174***	48.1841***	18.6476***	1.3699
LMerror	8.7003***	2.0255	0.4706	1.5566
R_LMerror	0.5941	23.0266***	12.4341***	2.2621

***,** and * indicate significance at the confidence levels of 1%, 5% and 10%, respectively.

When the LR test (Table S7), the *p*-values from both space-fixed effects and the time-fixed effects are significant ($p < 0.001$), rejected the null hypothesis of absence of both space-fixed and time-fixed effect, the next step was to include both the time-effect and the space-effect in the space panel model.

Table S7. Panel data model LR test results.

Effect	LR value	Degree of freedom	*p*-value
LR-test joint significance Space-fixed effects	320.2259	82	<0.001
LR-test joint significance Time-fixed effects	161.7916	4	<0.001

In the time-fixed and space-fixed models, LR and Wald test rejected SDM to be simplified into SLM or SEM. Meanwhile, in the space-time fixed model, the significances for the four parameters were lower comparing with either time fixed or space fixed model (Table S7). Therefore, it was necessary to compare space-fixed SLM, space-fixed SDM, time-fixed SLM and time-fixed SDM models (table S8), and choose the best fit model.

Table S8. SDM model Wald test and LR test results.

Spatial parameter	Space-fixed effects	Time-fixed effects	Space and time-fixed effects
Wald spatial lag	57.1361***	20.6512***	16.2996**
Wald spatial error	74.0232***	27.1154***	15.2978**
LR spatial lag	53.1247***	21.1740***	16.8392***
LR spatial error	92.1828***	24.5687***	15.7479**

***,** and * indicate significance at the confidence levels of 1%, 5% and 10%, respectively.

The significance of the estimation coefficients of the explanatory variables, the Corrected R2, and Log-Likelihood in Table S9, led to the space-fixed SDM model to be chosen as the best-fit model.

Table S9. Estimation results of panel model with different specific effects.

Model / Variable	Time-fixed effects SLM	Space-fixed effects SLM	Time-fixed effects SDM	Space-fixed effects SDM
Unemployment_Rate	0.171818***	0.099245**	0.149395***	0.05688
GRP	-0.000008	-0.000064***	-0.00001	-0.000063***
Education_index	-10.175992	11.315018	-11.827359*	7.203508
Urbanization_rate	-0.02334	0.022893	-0.023245	0.087084
Abortions_number	-0.003671	0.038717***	0.001144	0.013003*
Total_population	-0.000245**	0.001939**	-0.000133	0.002072**
W*Unemployment_Rate			0.088713	0.368495***
W*GRP			-0.000003	-0.000018
W*Education_index			-0.469711	36.097399***
W*Urbanization_rate			0.018721	-0.25294
W*Abortions_Number			-0.023457***	0.035208***
W*Total population			-0.000259	-0.00153
W*dep.var.	0.066976	0.343975***	0.025946	0.11899**
σ^2	7.2972	4.0284	6.7983	3.5106
R^2	0.6897	0.8287	0.7109	0.8507
Corrected R^2	0.242	0.7594	0.2903	0.7933
LogL	-790.39919	-698.41744	-779.81219	-671.8551

***,** and * indicate significance at the confidence levels of 1%, 5% and 10%, respectively.