A spatial analysis of school district performance in Minnesota, demonstrating spatially enabled evaluation

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Introduction

- Longitudinal analysis is commonly used in applied educational research, but spatial analysis is underutilized (Singer, 2008; Renger et al., 2002; Tate, 2008).
  - *Spatially enabled* social science disciplines, such as public health and economics, regularly use geographic maps and spatial methods to form research questions, to sample, collect, and analyze data, and to disseminate results (Waller & Gotway, 2004).
- Terms
  - *Spatial* is a general term that encompasses *geographic*
  - Spatial data can be stored and processed in *geographic information systems* (*GIS*), which produce maps

Research questions

- How can applied educational researchers make better use of geographic information systems (GIS) and spatial analysis?
- To what extent do school districts *perform* like their neighbors?
  - Which school districts are outperforming their neighbors?
  - Where should interventions be located?

Most promising uses

- Promote participation of evaluation stakeholders (Moore, 2007a; Craig & Elwood, 1998)
- Plan and implement surveys (Craun & Freisthler, 2008; Brown, 2005)
  - Power analysis and geographically stratified random sampling
  - Instruments that feature maps (Talen & Shah, 2007)
- Conduct cluster randomized trials (Raudenbush, 1997)
  - Assign areas to treatment conditions
- Implement quasi-experimental studies
  - Focal *and local* comparison groups (Shadish and Cook, 2009)
    - Propensity score matching with spatial predictors (Bondonio, 2002)
    - Spatial regression discontinuity at geographic borders (Moore, 2008)

Most promising uses (To be demonstrated)

- Spatially reference data and join covariates (Renger et al., 2002)
  - Enhance primary data (e.g., with Census data; Moore, 2007b)
  - Minimize respondent burden
- Employ spatial (and spatio-temporal) statistical analysis (Verbitsky, 2007)
- Disseminate evaluation information in statistical maps (Davenport, 2006)
  - Visual adjuncts promote comprehension of text (Verdi & Kulhavy, 2002)

Mitigating concerns

- Maps are inherently inaccurate and prone to mislead (Monmonier, 1996)
- Mere visual decoration and distraction (Carney & Levin, 2002)
- Violation of participants' privacy (where they live; Banerjee, Carlin, & Gelfand, 2004)
- Spatial autocorrelation complicates spatial statistical analysis (Anselin et al., 1996)

Spatial autocorrelation

- "Everything is related to everything else, but near things are more related than distant things." -Tobler's (1970) first law of geography
- Consequences
  - Larger sample sizes required for statistical power
  - Spatially naïve models can yield biased estimates when an important spatially lagged term is omitted
  - Neighbors can influence learning, all else being equal (Leventhal & Brooks-Gunn, 2000)

Spatial modeling

- Spatial weights matrix $\boldsymbol{W}$ ("proximity matrix")
  - Defines the neighborhood structure over the entire study area (Waller & Gotway, 2004)
  - *k* nearest neighbors style

$$w_{ij} = \begin{cases} 1/k & \text{if the centroid of region } j \text{ is one of the } k \text{ nearest to the centroid of region } i \\ 0 & \text{otherwise} \end{cases}$$

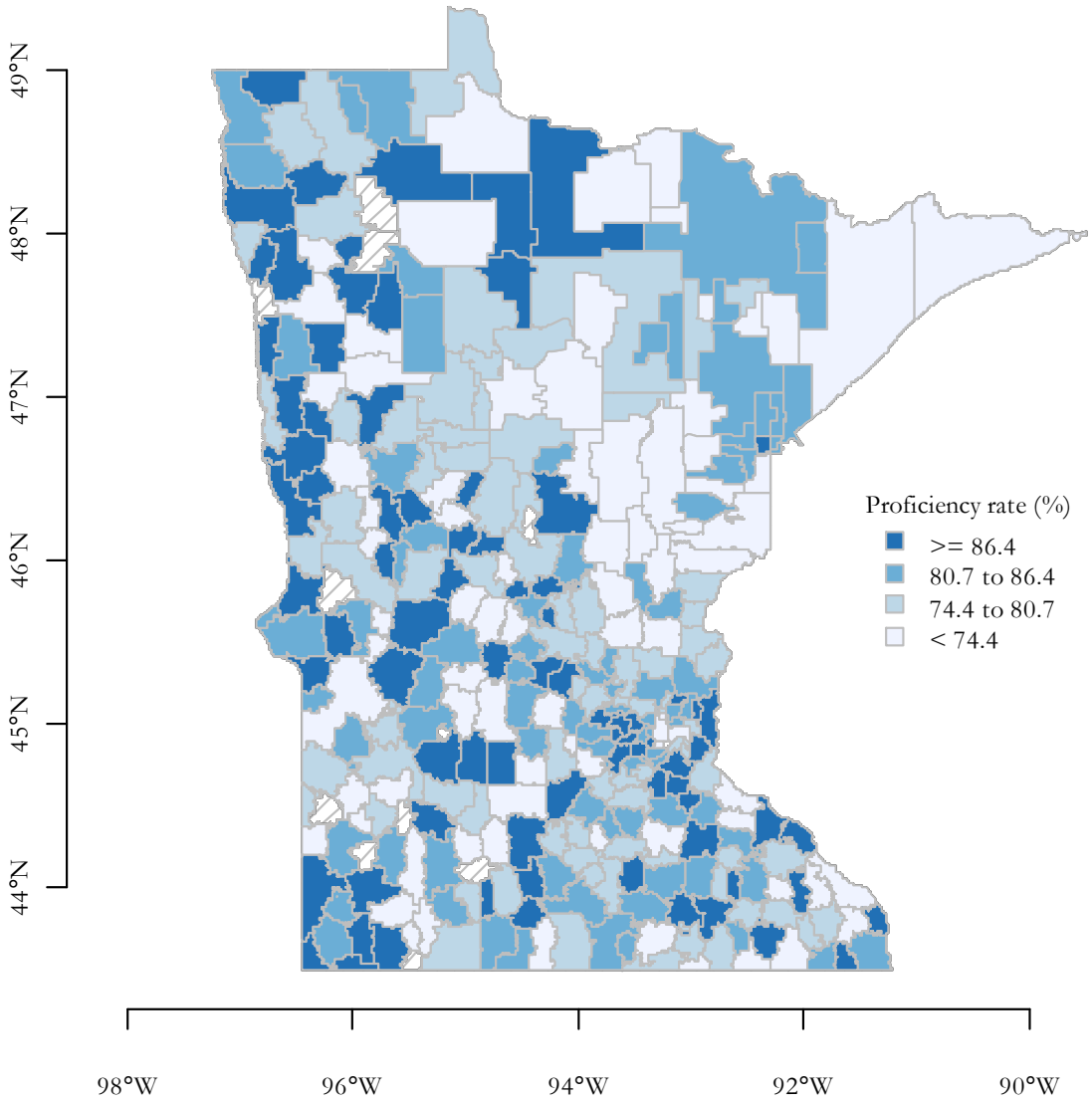
- Spatial lag model: $\boldsymbol{y} = \rho \boldsymbol{W}\boldsymbol{y} + \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}$

Third grade MCA-II* results in 2007: School district proficiency rates (%)

Dependent variable	Name	Districts	Mean	*SD*	Min.	Max.
Math						
All students	*MP*	328	79.6	10.1	36.9	100.0
Eligible for free or reduced lunch	*MPP*	314	71.5	14.8	11.1	100.0
Economic proficiency gap (poverty-affluent difference)	*MECONPD*	302	-13.1	14.3	-48.9	55.6
Students of color and/or Hispanic or Latino ethnicity (minority)	*MMINP*	279	67.0	28.9	0.0	100.0
Racial/ethnic proficiency gap (minority-white difference)	*MMINWPD*	276	-14.3	27.4	-90.9	54.5
Reading						
All students	*RP*	328	81.6	8.8	43.8	100.0
Eligible for free or reduced lunch	*RPP*	316	72.1	13.7	33.3	100.0
Economic proficiency gap (poverty-affluent difference)	*RECONPD*	302	-15.3	13.4	-54.5	25.0
Students of color and/or Hispanic or Latino ethnicity (minority)	*RMINP*	282	67.5	28.0	0.0	100.0
Racial/ethnic proficiency gap (minority-white difference)	*RMINWPD*	279	-16.8	27.8	-96.6	40.0

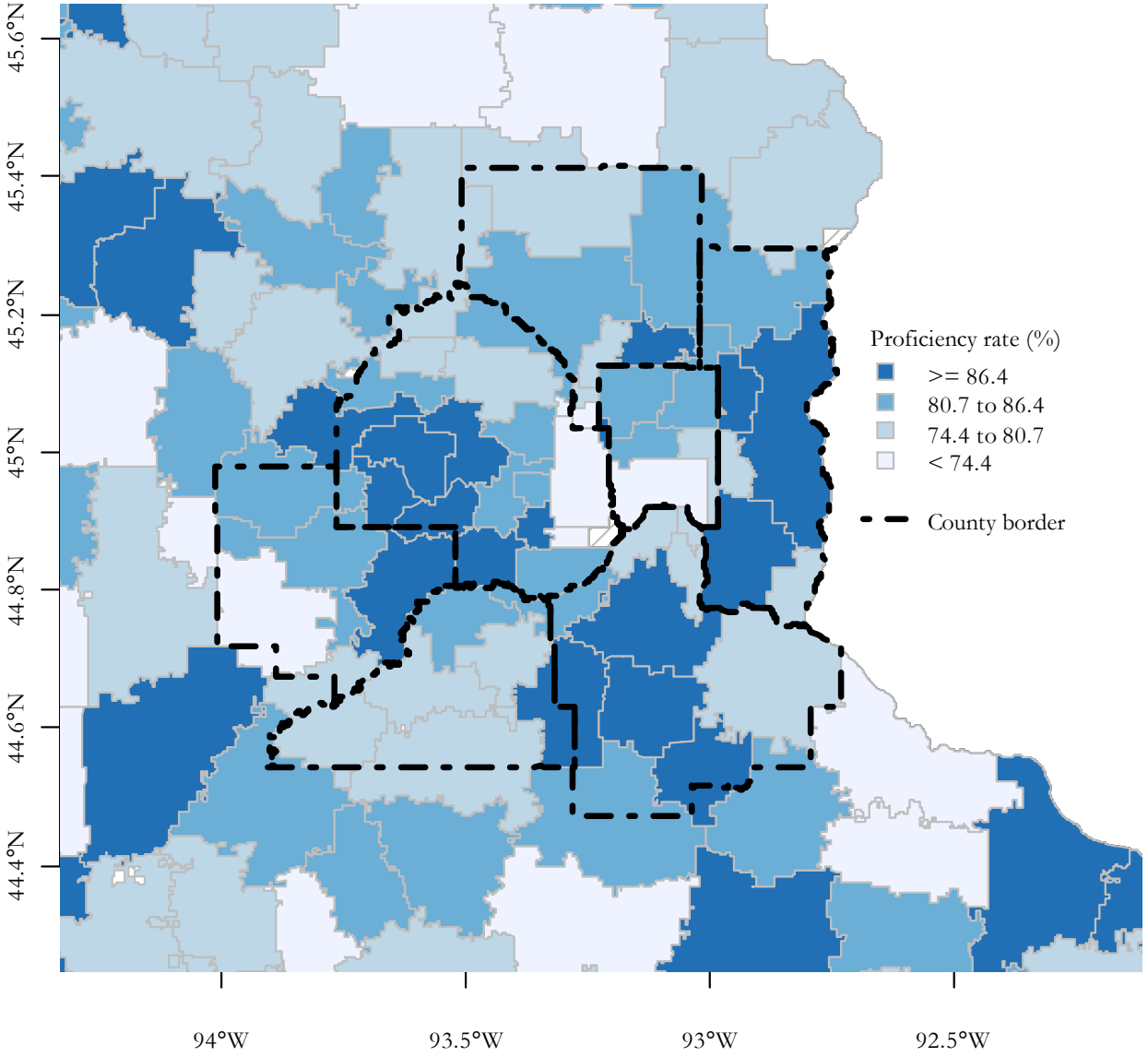
*Minnesota Comprehensive Assessment – Series II

School districts: Math proficiency among third graders

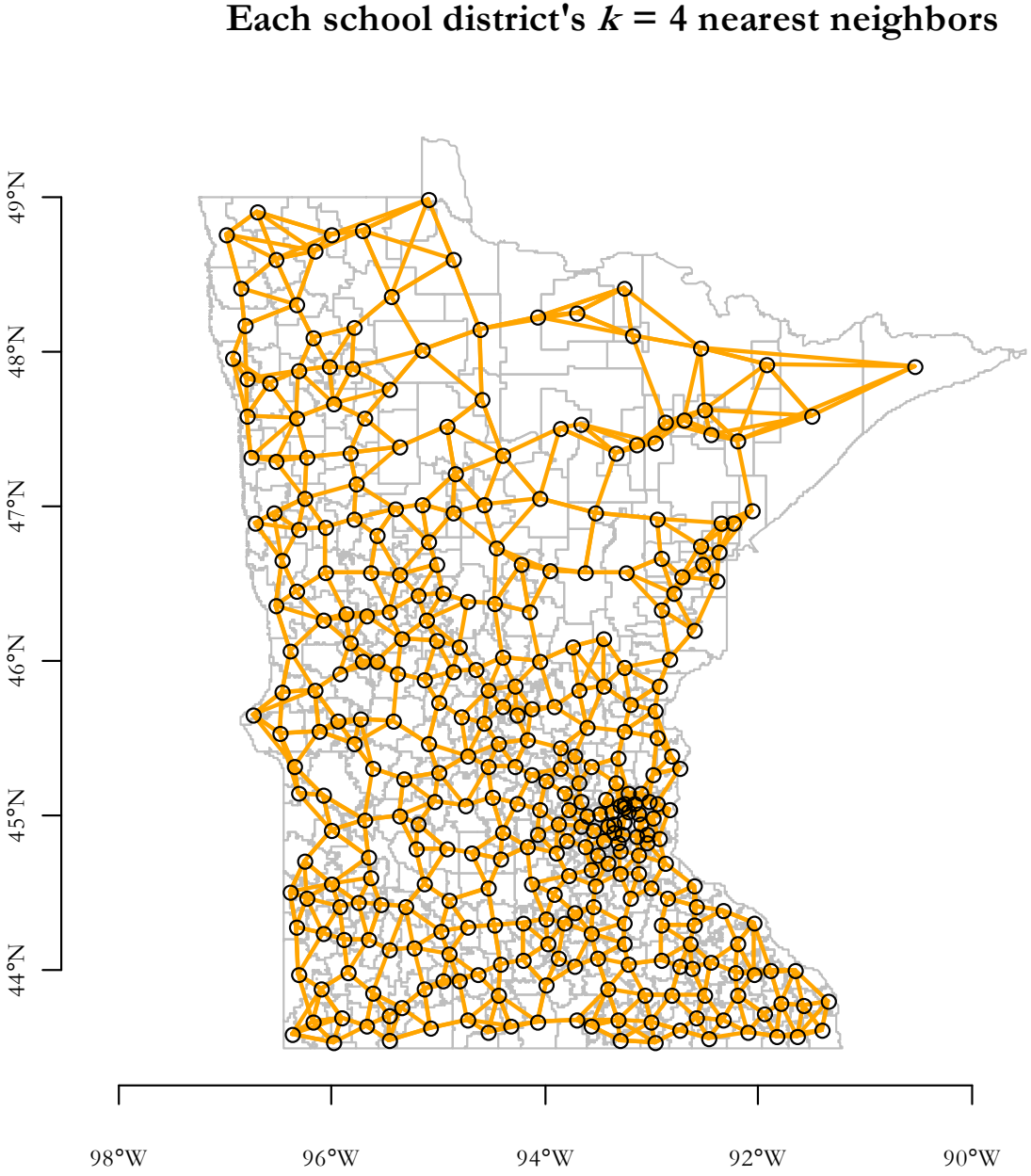


Minnesota

School districts: Math proficiency among third graders



Twin Cities metro area

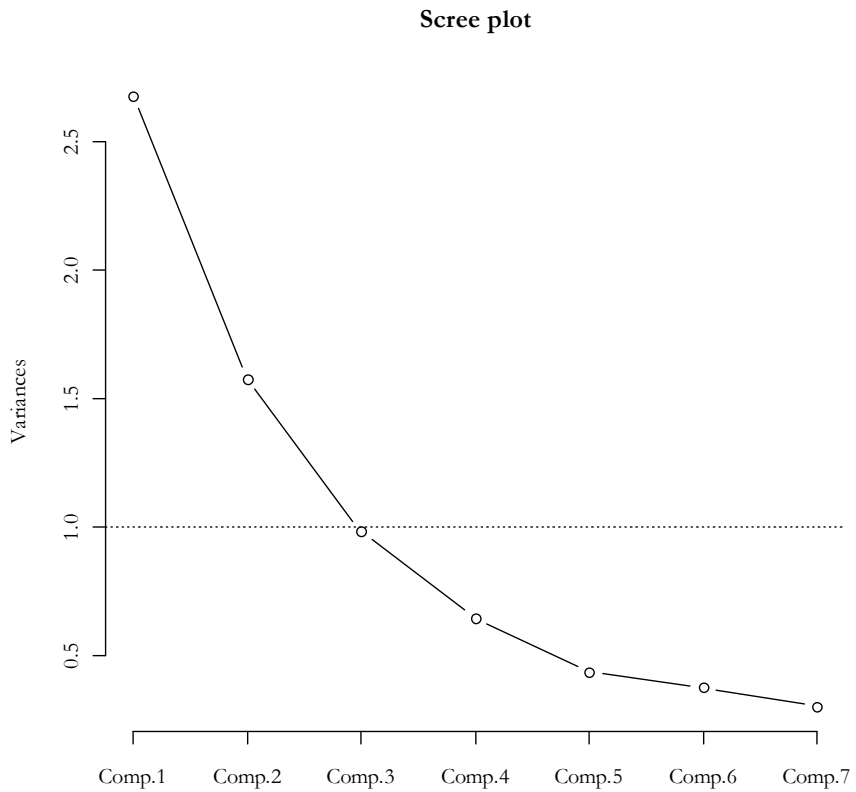


Values of $w_{ij} > 0$ in the spatial proximity matrix

Control variables: Demographics and revenue

Explanatory variable	Name	Districts	Mean	*SD*	Min.	Max.
Third graders enrolled	*ENROLL_G*	334	170.6	338.8	2	2,936
Third graders eligible for free or reduced lunch (%)	*PCT_P*	334	37.7	16.3	0.0	100.0
Third graders of color and/or Hispanic or Latino ethnicity (%)	*PCT_MIN*	334	12.1	16.0	0.0	100.0
Local property taxes per average daily membership (ADM)	*PROPTREV*	334	$1,408	$711	-$114	$4,053
Other local revenue per ADM	*LOCREVO*	334	$1,215	$660	$357	$7,154
State revenue per ADM	*STATEREV*	334	$7,753	$994	$5,496	$12,662
Federal revenue per ADM	*FEDREV*	334	$663	$1,123	$108	$17,358

Factor analysis results



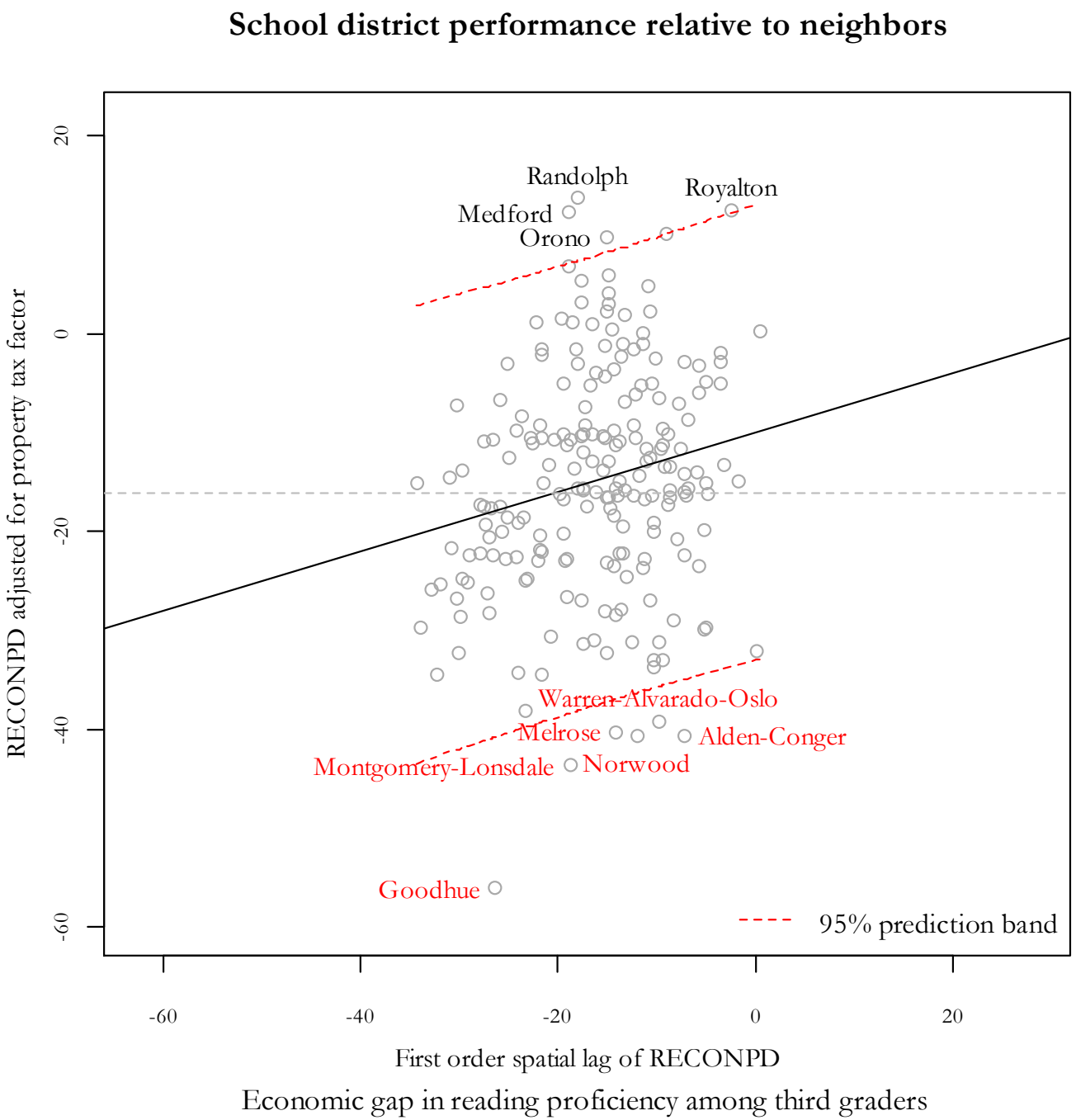
	Factor 1: Redistribution	Factor 2: Property tax reliance
PCT_P	**0.80**	-0.10
FEDREV	**0.78**	0.11
STATEREV	**0.70**	-0.09
PCT_MIN	0.38	**0.72**
ENROLL_G	-0.29	**0.72**
PROPTREV	-0.24	**0.41**
LOCREVO	-0.03	0.21
Cumulative proportion of variance extracted	0.29	0.47
Factor correlation	-0.23	

Results for reading proficiency among third graders in poverty

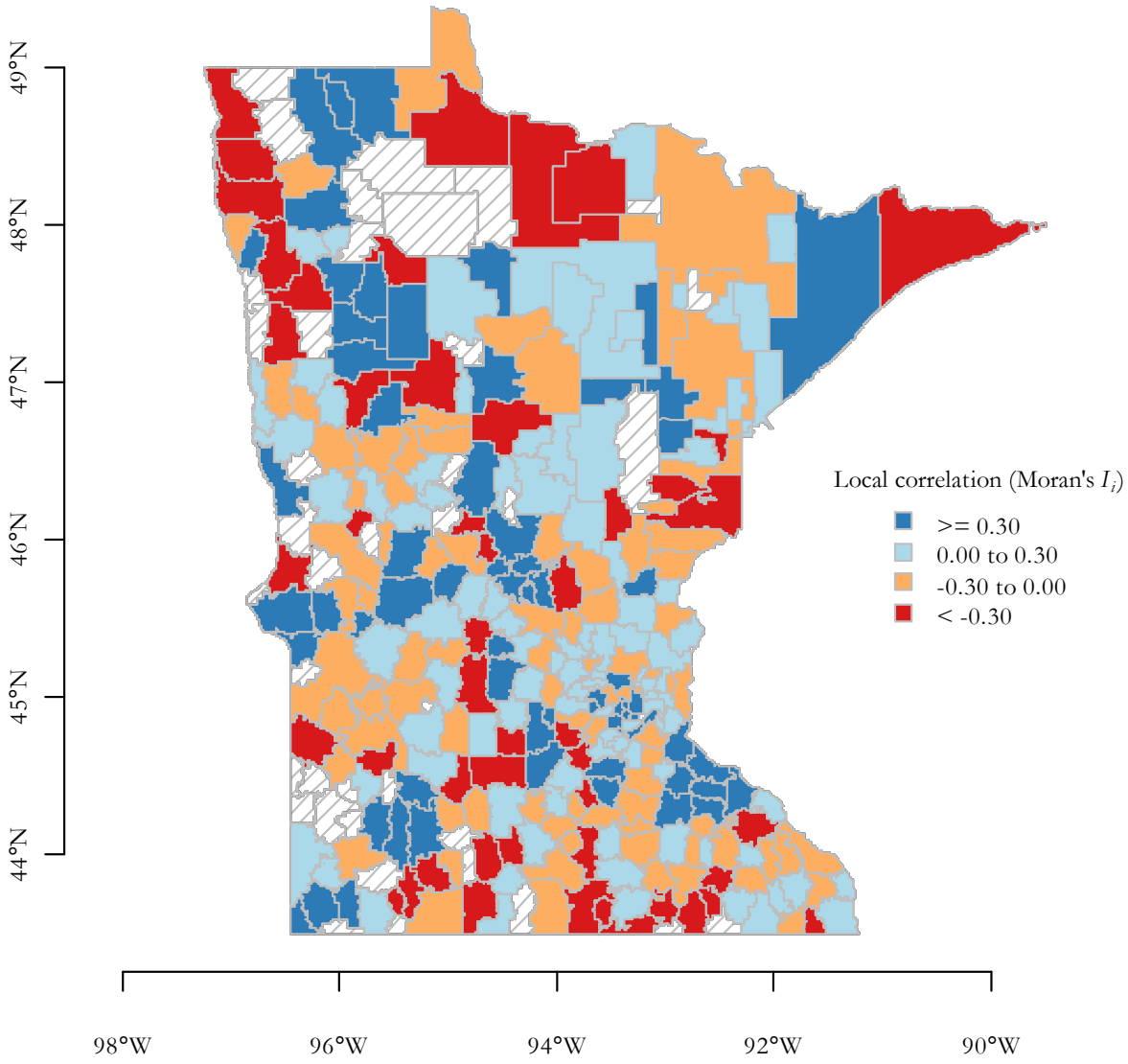
	Preliminary model				Final model				
	Estimate	Robust *SE*	*t*	*p*	Estimate	Robust *SE*	*t*	*p*	Standardized est. [95% *CI*]
Intercept	50.22	8.57	5.86	0.000	49.71	8.59	5.79	0.000	
RPP lagged	0.30	0.12	2.57	0.011	0.31	0.12	2.63	0.009	0.17 [0.04, 0.29]
Redistribution factor	-1.53	0.84	-1.82	0.070					
Property tax factor	-3.00	0.96	-3.14	0.002	-2.46	0.91	-2.69	0.008	-0.18 [-0.31, -0.05]
Fit									
R^2 adj.	0.084				0.078				
F (*df*)	10.04 (3, 245)			<0.001	13.07 (2, 246)			<0.001	

Results for economic gap in reading proficiency among third graders

	Preliminary model				Final model				
	Estimate	Robust *SE*	*t*	*p*	Estimate	Robust *SE*	*t*	*p*	Standardized est. [95% *CI*]
Intercept	-10.22	1.92	-5.33	0.000	-9.93	1.89	-5.25	0.000	
RECONPD lagged	0.31	0.12	2.63	0.009	0.30	0.12	2.59	0.010	0.17 [0.04, 0.30]
Redistribution factor	-1.53	0.95	-1.61	0.110					
Property tax factor	-3.82	0.98	-3.91	0.000	-3.59	0.95	-3.77	<0.001	-0.27 [-0.41, -0.13]
Fit									
R^2 adj.	0.145				0.140				
F (*df*)	15.7 (3, 204)			<0.001	21.09 (2, 205)			<0.001	


School district performance relative to neighbors
RECONPD adjusted for property tax factor
20
0
-20
-40
-60
Randolph
Royalton
Medford
Orono
Warren-Alvarado-Oslo
Melrose
Alden-Conger
Montgomery-Lonsdale
Norwood
Goodhue
95% prediction band
-60
-40
-20
0
20
First order spatial lag of RECONPD
Economic gap in reading proficiency among third graders

School district clusters and hotspots (*RECONPD* adjusted)



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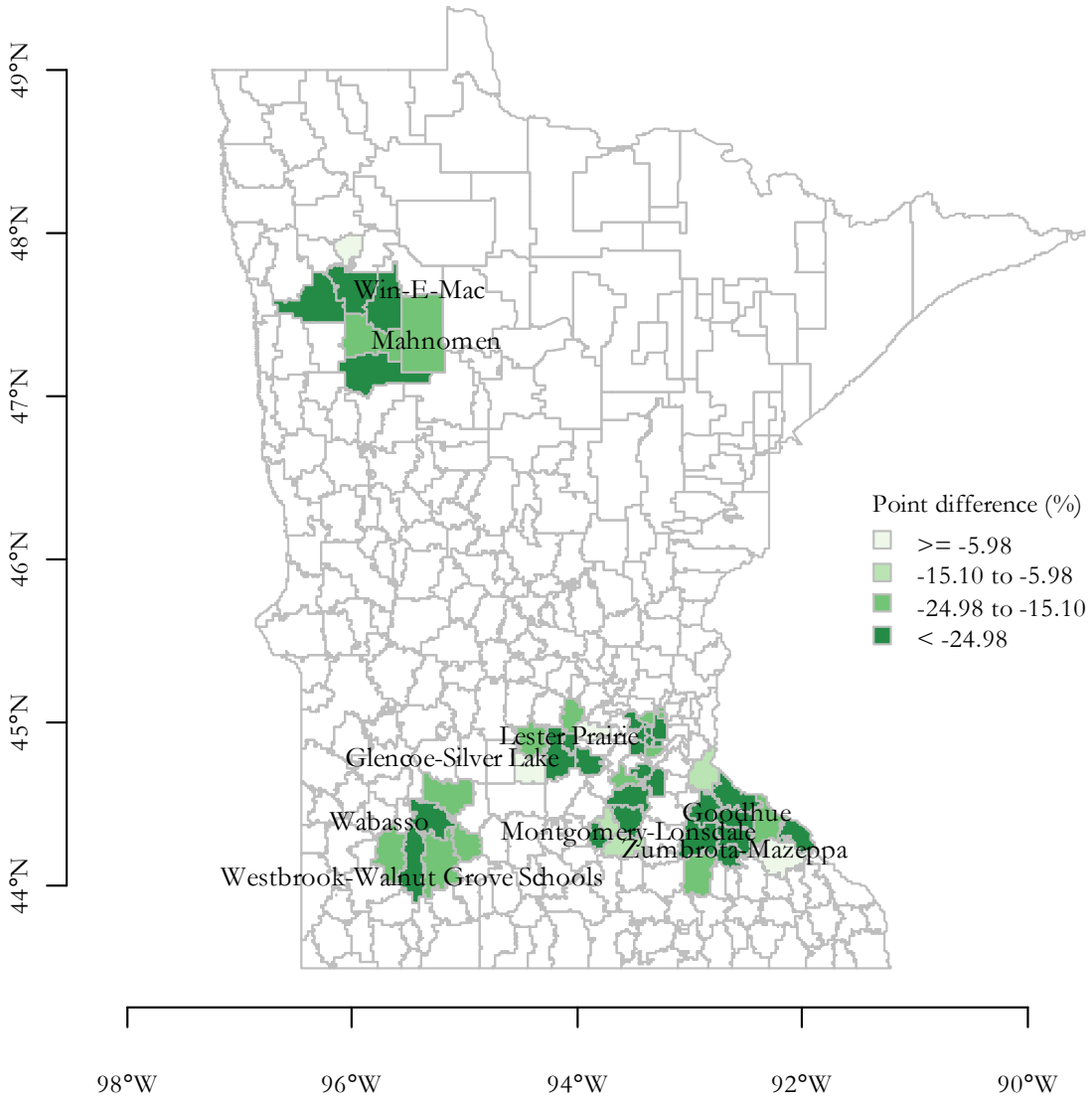
Early reading intervention clusters: Economic proficiency gap



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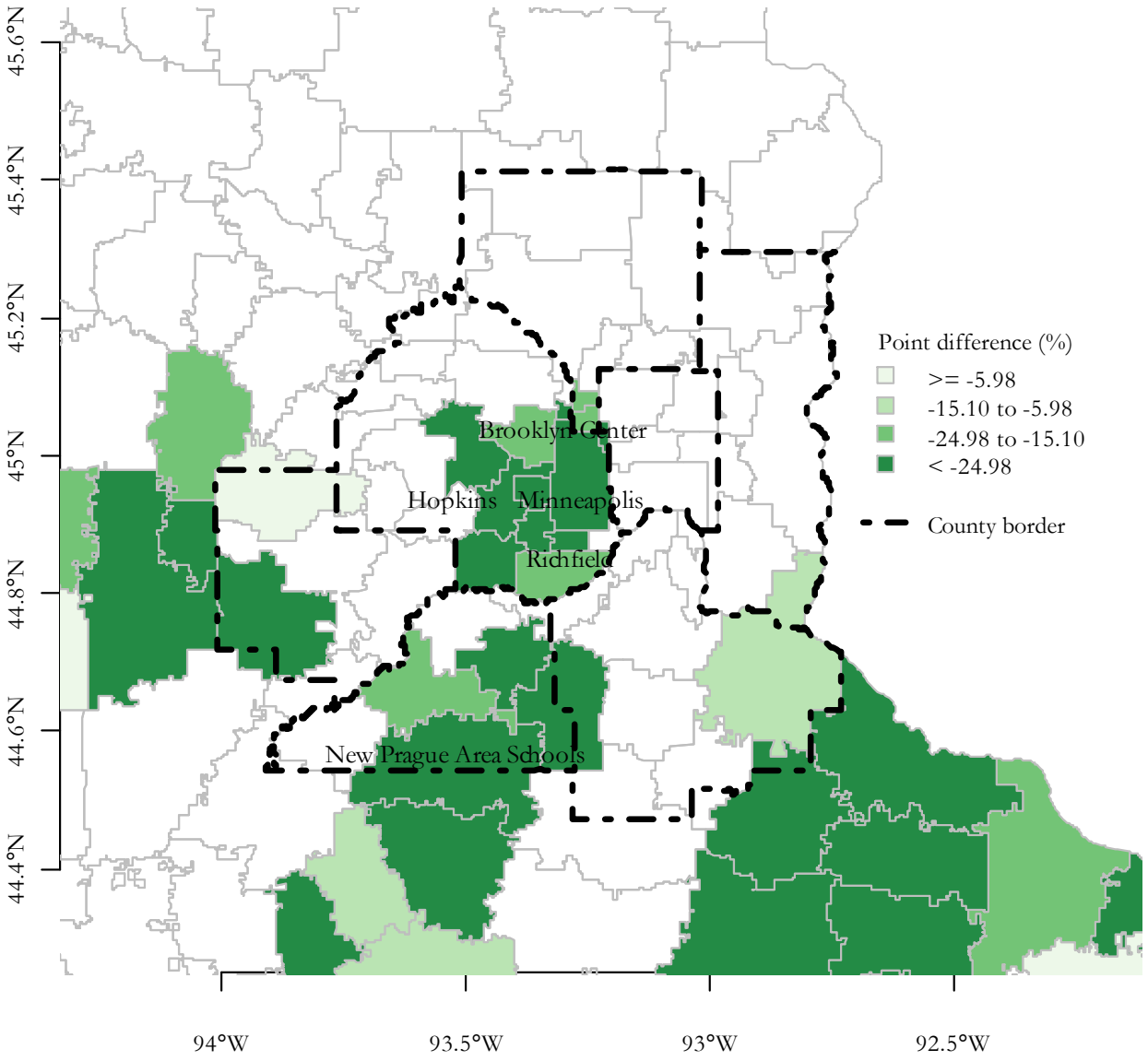

Twin Cities metro area

Conclusions

- Educational researchers can make better use of spatial methods by adopting techniques from spatially enabled disciplines, by managing the risks, and by continuing to make their own contributions (e.g., research on spatial cognition, systematic judgment of merit).
- Neighboring school districts influence performance to a small degree in limited instances (reading proficiency of third graders in poverty).

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