Why Public Health Needs GIS?

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Louisiana State University

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Contents

1. Geographic heterogeneity
2. S/D interaction across borders
3. Neighborhood effect
4. Small population problem
5. Delineating healthcare markets
6. Toward equality
☐ recap
1. “One size does NOT fit all”

Late-stage cancer risks in IL 1998-2002
African American (Relative to Whites) Colorectal/Breast Cancer Screening 2001-05

Hispanic Effect on Colorectal and Breast Cancer Screening Rates

Colorectal Cancer Screening Rate 2001 - 2005

Breast Cancer Screening Rate 2003 - 2005
NATIONAL ESTIMATE: 0.000

Significantly Negative State Effect Estimate
Significantly Positive State Effect Estimate
State Estimate Not Statistically Significant
Significantly Negative State Effect Estimate

Significantly Positive State Effect Estimate
State Estimate Not Statistically Significant
Significantly Negative State Effect Estimate

NATIONAL ESTIMATE: 0.030
Obesity rate in the U.S. 2012

Multilevel logistic models for risk of obesity by urbanicity (urban ratio range).

<table>
<thead>
<tr>
<th>Component</th>
<th>Completely urban (0.99–1.00)</th>
<th>Highly urban (0.90–0.99)</th>
<th>Mostly urban (0.50–0.89)</th>
<th>Marginally urban (0.01–0.49)</th>
<th>Completely rural (0–0.01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.13670***</td>
<td>0.13880***</td>
<td>0.07865***</td>
<td>0.09523***</td>
<td>0.02024***</td>
</tr>
<tr>
<td>Individual-level variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>0.03315***</td>
<td>−0.00856*</td>
<td>−0.01254***</td>
<td>−0.0184</td>
<td>−0.01152</td>
</tr>
<tr>
<td>Age (18+)</td>
<td>0.01993***</td>
<td>0.0185***</td>
<td>0.01954***</td>
<td>0.01828***</td>
<td>0.01918***</td>
</tr>
<tr>
<td>Age squared</td>
<td>−0.00019***</td>
<td>−0.00019***</td>
<td>−0.00019***</td>
<td>−0.00019***</td>
<td>−0.00026***</td>
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<tr>
<td>Hispanic</td>
<td>−0.01487</td>
<td>−0.00784</td>
<td>0.000334</td>
<td>0.00845</td>
<td>0.02436</td>
</tr>
<tr>
<td>Married</td>
<td>−0.02567***</td>
<td>−0.0184**</td>
<td>−0.0034</td>
<td>0.00734</td>
<td>0.00398</td>
</tr>
<tr>
<td>Education (1–6)</td>
<td>−0.04797***</td>
<td>−0.03150**</td>
<td>−0.02752**</td>
<td>−0.01900**</td>
<td>−0.01371**</td>
</tr>
<tr>
<td>Employed</td>
<td>0.00172</td>
<td>0.00623</td>
<td>0.01091**</td>
<td>0.01879**</td>
<td>0.01924</td>
</tr>
<tr>
<td>Income (1–8)</td>
<td>−0.01382***</td>
<td>−0.01793***</td>
<td>−0.01683**</td>
<td>−0.01761**</td>
<td>−0.01881**</td>
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<tr>
<td>Smoker</td>
<td>−0.01065</td>
<td>−0.03183***</td>
<td>−0.04682**</td>
<td>−0.04918**</td>
<td></td>
</tr>
<tr>
<td>County-level variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poverty</td>
<td>0.00005</td>
<td>0.00828</td>
<td>0.00638**</td>
<td>0.00196**</td>
<td>0.00237***</td>
</tr>
<tr>
<td>Population-adjusted street connectivity</td>
<td>0.00002</td>
<td>−0.00039***</td>
<td>−0.00006</td>
<td>−0.00014</td>
<td>0.00021</td>
</tr>
<tr>
<td>No. observations</td>
<td>17,428</td>
<td>43,763</td>
<td>99,711</td>
<td>88,500</td>
<td>21,846</td>
</tr>
<tr>
<td>AIC</td>
<td>9038.2</td>
<td>7804.3</td>
<td>4118.4</td>
<td>1346.4</td>
<td>6136.2</td>
</tr>
</tbody>
</table>

*** Statistically significant at 0.001, ** statistically significant at 0.01, * statistically significant at 0.05.
* Range of urban ratio in parenthesis.
Household energy expenditure in Netherland 2014

Table 3. Estimates of SGWR model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Spatial</th>
<th>Intercept</th>
<th>Household size</th>
<th>Private rent</th>
<th>Low income (%)</th>
<th>Unemployment (%)</th>
<th>Pensioner (%)</th>
<th>Building age</th>
<th>Number of summer days</th>
<th>Number of frost days</th>
<th>$R^2$</th>
<th>Adjusted $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td></td>
<td>0.4</td>
<td>0.1</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| $\beta$: standardized regression coefficient. 
**p value < 0.01.**

Most influential localized determinants of HEE

- No localized determinant increasing HEE
- Household size
- Private rent
- Unemployment
- Building age
- Number of summer days
- Number of frost days

- 55.2%
- 11.4%
- 12.8%
- 5.0%
- 3.0%
- 12.3%

Map of Netherland showing different regions and their corresponding energy expenditure data.
Reflection

- Distinctive dynamics in various geographic settings
- GIS is best at delineating them
- SGWR sorts out global vs. local effects
- One-size-fits-all public policy approach is wasteful and ineffective
2. “No wall”
2SFCA

Integrated Designation

Legend
- Poor Spatial Access
- Marginal Spatial Access and High Needs
- Poor Socioeconomic Status
- Marginal Socioeconomic Status
- and Socio-Cultural Barrier
- County Boundary

(Spatial access criteria: score < 1/3500 or < 1/3000 if there is high needs)
From 2SFCA to Inverted-2SFCA

- Capture availability at each supply: \( \frac{S}{\Sigma P} \)
- Sum up accessible supplies around each demand: \( \Sigma \left( \frac{S}{\Sigma P} \right) \)
- Capture competition intensity at each demand: \( \frac{P}{\Sigma S} \)
- Sum up reachable demands around each supply: \( \Sigma \left( \frac{P}{\Sigma S} \right) \)

Facility crowdedness

Resident accessibility
Resident accessibility vs. Hospital crowdedness
Reflection

- Both proximity & availability matter in access to service
- Patients and service providers interact beyond unit borders
- GIS captures spatial behavior
- Geographic precision leads to policy precision and cost saving
3. “It depends on what the meaning of ‘it (neighborhood)’ is”

<table>
<thead>
<tr>
<th>True state of contextual effect</th>
<th>Observed state of contextual effect</th>
<th>Has effect</th>
<th>No effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has effect</td>
<td>Contextual units correct</td>
<td>Contextual units incorrect</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Correct inference</td>
<td>False negatives (obscured contextual effect)</td>
<td></td>
</tr>
<tr>
<td>No effect</td>
<td>Contextual units incorrect</td>
<td>Correct units correct</td>
<td></td>
</tr>
<tr>
<td></td>
<td>False positives (spurious association)</td>
<td>Correct inference</td>
<td></td>
</tr>
</tbody>
</table>
Obesity risk in Utah 2007-2011

Adjusted odds ratios (95% Confidence interval) of the multilevel logistic models for odds of overweight or obesity (BMI ≥ 25).

<table>
<thead>
<tr>
<th>Individual-level variables</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (18+)</td>
<td>1.135***</td>
<td>1.136***</td>
<td>1.136***</td>
</tr>
<tr>
<td>Age²</td>
<td>0.999***</td>
<td>0.999***</td>
<td>0.999***</td>
</tr>
<tr>
<td>Female</td>
<td>0.475***</td>
<td>0.475***</td>
<td>0.475***</td>
</tr>
<tr>
<td>White</td>
<td>1.058</td>
<td>1.058</td>
<td>1.054</td>
</tr>
<tr>
<td>Married</td>
<td>1.039</td>
<td>1.039</td>
<td>1.040</td>
</tr>
<tr>
<td>College</td>
<td>0.823***</td>
<td>0.824***</td>
<td>0.820***</td>
</tr>
<tr>
<td>Self-employed</td>
<td>0.820***</td>
<td>0.821***</td>
<td>0.821***</td>
</tr>
<tr>
<td>Out of work for more than 1 year</td>
<td>0.964</td>
<td>0.964</td>
<td>0.962</td>
</tr>
<tr>
<td>Out of work for less than 1 year</td>
<td>0.967</td>
<td>0.970</td>
<td>0.969</td>
</tr>
<tr>
<td>Homemaker</td>
<td>0.734***</td>
<td>0.734***</td>
<td>0.734***</td>
</tr>
<tr>
<td>Student</td>
<td>0.861*</td>
<td>0.859</td>
<td>0.858</td>
</tr>
<tr>
<td>Retired</td>
<td>0.941</td>
<td>0.941</td>
<td>0.942</td>
</tr>
<tr>
<td>Smoker</td>
<td>0.945*</td>
<td>0.945*</td>
<td>1.768*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zip code-level variables</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poverty</td>
<td>2.104**</td>
<td>2.376*</td>
<td>1.768</td>
</tr>
<tr>
<td>Street connectivity</td>
<td>1.000</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Walk Score</td>
<td>1.000</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td><strong>Distance to park</strong></td>
<td>1.009</td>
<td>1.014*</td>
<td>1.012***</td>
</tr>
<tr>
<td>Fast food accessibility</td>
<td>0.999*</td>
<td>0.999</td>
<td></td>
</tr>
<tr>
<td>Metro</td>
<td>1.003</td>
<td>0.975</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>County-level variables</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poverty</td>
<td>0.997</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Street connectivity</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walk Score</td>
<td>1.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to park</td>
<td>0.991</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ratio of fast-food to full-service</strong></td>
<td>1.128***</td>
<td>1.120***</td>
<td></td>
</tr>
<tr>
<td>Metro</td>
<td>0.926</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sample size: 21,961 individuals living in 299 zip codes, 29 counties.

***p ≤ 0.001, **p ≤ 0.01, *p ≤ 0.05 (two-tailed tests).
Dynamic exposure to green space & mental health

A) Person’s daily mobility path
   - Home
   - Work
   - Leisure

B) Person’s residential life course
   - 1980: Rotterdam
   - 1996: Utrecht
   - 2017: Almere
Personal Air Quality Index
Reflection

☑ Policies at different levels of jurisdiction
☑ From neighborhood to “ego-hood”
☑ Activity space varies by activity purpose by demographic groups
☑ Dynamic exposure to environment
☑ GIS enables defining “individualized” neighborhoods
4. “Let the Data Speak for Themselves”?

- Small population problem
  - Unreliable
  - Sensitive to data errors
  - Statistical distribution
  - Data suppression

- Regionalization: constructing larger areas

Incidence Rates for Louisiana, 2001 - 2005
Brain & ONS
All Races (includes Hispanic), Both Sexes, All Ages

Age-Adjusted Annual Incidence Rate (Cases per 100,000)

Quartile Interval

US (SEER + NPCR)
Rate (95% C.I.)
6.7 (6.6 - 6.7)

Louisiana
Rate (95% C.I.)
5.8 (5.5 - 6.2)
Mixed-Level Regionalization (MLR)

\[ O_i = w_s O_{si} + w_a O_{ai} \]
Louisiana
Cancer rates before & after MLR

A

B

Cancer incidence per 100,000 population
(Std. Dev. values are based on tract level)

- < -1.5 Std. Dev. (0 - 141)
- -1.5 - 0.50 Std. Dev. (143 - 394)
- 0.50 - 0.50 Std. Dev. (394 - 647)
- 0.50 - 1.5 Std. Dev. (647 - 899)
- > 1.5 Std. Dev. (900 - 1923)
Reflection

- More reliable rates in the new areas
- New rates conform to a normal distribution
- Larger areas to mask privacy
- Mitigating spatial autocorrelation
- GIS frees us from pre-defined arbitrary analysis unit(s)
5. “Act Locally”

**About Our Regions**

**Hospital referral regions (HRRs)** represent regional health care markets for tertiary medical care that generally requires the services of a major referral center. The regions were defined by determining where patients were referred for major cardiovascular surgical procedures and for neurosurgery. Each hospital service area (HSA) was examined to determine where most of its residents went for these services. The result was the aggregation of the 3,436 hospital service areas into 306 HRRs. Each HRR has at least one city where both major cardiovascular surgical procedures and neurosurgery are performed.

**Hospital service areas (HSAs)** are local health care markets for hospital care. An HSA is a collection of ZIP codes whose residents receive most of their hospitalizations from the hospitals in that area. HSAs were defined by assigning ZIP codes to the hospital area where the greatest proportion of their Medicare residents were hospitalized. Minor adjustments were made to ensure geographic contiguity. This process resulted in 3,436 HSAs. When these regions were created in the early 1990s, most hospital service areas contained only one hospital. In the intervening years, hospital closures have left some HSAs with no hospital; these HSAs have been maintained as distinct areas in order to preserve the continuity of the database.

**Pediatric surgical areas (PSAs)** are regional markets for pediatric surgery. In order to define geographic markets for pediatric surgery in Northern New England, we aggregated hospital service areas based on children’s travel for common ENT procedures and appendectomies. This resulted in 30 pediatric surgical areas in Northern New England.

**Primary care service areas (PCSAs)** reflect Medicare patient travel to primary care providers. Version 3.1 (based on 2010 Census tracts) will be available soon from the Health Resources & Services Administration (HRSA).
Hospital Service Areas (HSAs) by the Huff Model

\[ P_{ij} = \frac{S_j \sigma f(d_{ij})}{\sum_{k=1}^{n} S_k \sigma f(d_{ik})} \]
HSAs in FL
CSAs in Northeast U.S.
Reflection

- HSA is a basic unit for healthcare assessment, management and planning
- WHO promotes healthcare localization
- Pursuit of *automated, data-driven, optimal* delineation of HSAs
- GIS defines HSAs that are maximally coherent
6. “Some are more equal than others”

\( p \)-median solution
Planning NCI Cancer Centers
Integrated approach

- two-step optimization for spatial accessibility improvement (2SO4SAI)
- S1: site facilities for efficiency
- S2: adjust their capacities for equality
Xiantao, Hubei
Reflection

- Efficiency vs. equality
- Pursuit of equality in access not outcome
- How much equality vs. what equality
- Location adjustment favored over resource allocation
- GIS in Spatially-integrated Social Sciences, Public Policy & Planning (S3P3)
Recap

- Human behavior varies geographically, so should policy
- S-D interact beyond borders
- Neighborhood needs to capture activity space & policy domain
- Turn the small population “problem” to an advantage
- Localize health care market
- Toward equality
Take-home message

- Public policy negligent of geography costs $ and lives!
- Geography is the reality of complexity we live in. *Deal with it!*
- GIS is the *renaissance* of geography
Funding & References

1. R21-CA114501 (NCI) & R01CA140319-01A1 (NIGMS)

2. R03-HS11764 (AHQR)
References

3. R01CA140319-01A1 (NIGMS)

4. N01-PC-54402 (NCI)

5. R21CA212687 (NCI)
References

6. (R01 from NCI?)
Thank You!

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