UNDERSTANDING HEALTH CARE UTILIZATION USING GEOGRAPHICAL WEIGHTED REGRESSION
AGENDA

1. Motivation
2. Measure of Regional Health Care Utilization using GWR
3. First Results
Approach by Sundmacher & Ozegowski 2014 / Culyer & Wagstaff 1993

• Need is the "expenditures required to exhaust a person's capacity to benefit“.
  • In Germany every individual “is entitled to the full coverage of any necessary treatment, under the condition that the treatment is provided economically and according to current standards of medical knowledge (Section 70(1) SGB V)“.

• Different risk-structures / need are compensated through the German risk structure compensation scheme (RSCS) showing the average need of a person controlling for age, sex and morbidity on the perspective of statutory health insurances.

➢ Assume that the average need is represented through the RSCS.
Motivation

The German risk structure compensation scheme (RSCS)

\[ S_i = \beta_A A_i + \beta_M M_i + \beta_D D_i + \beta_F F_i + e_i = EN_i + e_i \]

- Health care costs (S),
- Expected need (EN),
- Age and gender, in 5-year-sex-specific groups (A),
- Morbidity, measured by 80 diseases aggregated into 192 disease groups (M),
- Disability pension as proxy for further need (D),
- Living abroad (F)
Measurement of regional inequity in health care

- Inequity is defined as ratio between health care utilisation and need in a predefined region $j$ in terms of the RSCS in
  $$I_j = \frac{\sum_{i \in j} S_i}{\sum_{i \in j} EN_i}$$

- Overuse: $I_j > 1$ with more health care costs than expected need
- Underuse: $I_j < 1$ with less health care costs than expected need

- Problem:
  - Which definition of $j$ (zones) is suitable for this purpose?
  - What happens if we choose arbitrary ones?
  - Are there intrinsically different Problems for health care costs?
Mapping the spatial inequities between need and health care utilisation

Sundmacher & Ozegowski 2014
ambulatory costs

Drösler et al. 2009
overall costs
Motivation

Mapping the spatial inequities between need and health care utilisation

own calculation for overall costs on zip-regions and rural districts
Problems associated with zone definition

• The Area to Point Problem (A-, B- and C-type errors)
  • A: zonal statistics refer to a single point rather to a set of points
  • B: the distance within a zone is assumed to be zero (access to every place at zero costs)
  • C: no windfall gain of supply for other zones and perfectly association of zone and supply

• The Multiple Area Unit Problem (MAUP)
  • aggregation-variant of results (the finer the less we see, the wider the less we find)
  • scale-variant of the zones (boundary problem)

• The Yule-Simpson-effect
  • omitted variable bias through different geographical requirements
  • ecological fallacy while interpreting area results as individual behaviour
The German risk structure compensation scheme (RSCS)

\[ S_i = \beta_A A_i + \beta_M M_i + \beta_D D_i + \beta_F F_i + \beta_K * K_i + e_i = EN_i + e_i \]

- Health care costs (S),
- Expected need (EN),
- Age and gender, in 5-year-sex-specific groups (A),
- Morbidity, measured by 80 diseases aggregated into 192 disease groups (M),
- Disability pension as proxy for further need (D),
- Living abroad, which is not considered as we are interested in regional differences
- Dying as proxy for high costs in the last month of living (K)

- Using a contemporaneous classification of 2013 (BVA / [http://www.bundesversicherungsamt.de/riskostrukturausgleich/festlegungen.html](http://www.bundesversicherungsamt.de/riskostrukturausgleich/festlegungen.html))
Integrating regional inequities into the model through GWR

\[ S_i = I(u_i, v_i) + EN_i + e_i \quad / \quad S = I + \beta \cdot X + E \]

- Integration a factor of regional requirements / inequities through the point specific \( \hat{I}(u_j, v_j) \) where \((u_j, v_j)\) are coordinates in the space of observation.

- Weighted moving window regression method developed by Foterhingham and Brundson (2000, 2002), building on works of Hastie and Tibshirani (1990) and Loader (1999)

- Uses weighted least squares approach
Integrating regional inequities into the model through GWR

\[ S_i = I(u_i, v_i) + EN_i + e_i \quad \text{and} \quad S = I + \beta \cdot X + E \]

\[ \hat{I}(u_j, v_j) = \left(1'W(u_j, v_j)1\right)^{-1}1'(S - \beta \cdot X) \]

- Separate regression is run for each observation, using a spatial kernel that centers on a given point and weights observations subject to a distance decay function.
- An adaptive kernel is used as data is not evenly distributed.
Bias and variance trade-off

- The smaller the bandwidth (N), the more variance but the lower the bias, the larger the bandwidth, the more bias but the more variance is reduced.
- This is because we assume there are many betas over space and the more it is like a global regression, the more biased it is.
- BIC minimization provides a way of choosing bandwidth that makes optimal tradeoff between bias and variance.

\[ BIC = n \times \ln \left( \frac{\sigma_e^2}{\hat{\sigma}_e^2} \right) + tr(S) \times \ln(n) \]

Where \( tr(S) \) is the trace of the hat matrix and \( n \) is the number of observations.
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Data considerations

• Information of German statutory health insurances including 1.8 million individuals.

• A sample of 1.5 million individuals is drawn randomly controlling for age, sex and morbidity on the administrative level of rural districts.

• All individuals are georeferenced on their place of residence to calculate UTM coordinates \((u_i, v_i)\).

• A grouping of the diseases into disease-groups is done through the German RSCS using the contemporaneous classification of 2013.

• To control for extreme values a “Huber M-Estimator” is used instead of a weighted regression.

• Estimates or done on a 5x5km grid of Germany for ambulatory, stationary, pharmaceutic and overall costs.
First Results

Where we come from:

own calculation for overall costs on zip-regions and districts
Overall inequity between need and utilisation

Legend

- **Cities (>250,000)**

**Overall (I)**

Red colour
means more utilisation than expected need. It refers to an oversupply for the sick and a negative marginal return for statutory sickness funds. A number of 10 means 10 Euro more utilisation than expected.

Green colour
means more expected need than the actual utilisation. It refers to an undersupply for the sick and a positive marginal return for statutory sickness funds. A number of -10 means 10 Euro less utilisation than expected.

Data: cost p.c. of 1.5 million observations
Method: GWR
Kernel: adaptive bi-squared
Parametrisation: N=66,000

Date: ETRS 1989 LAEA
Author: Danny Wende
First Results

The bandwidth selection

Costs

<table>
<thead>
<tr>
<th>Costs</th>
<th>optimal bandwidth (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ambulatory</td>
<td>64,000</td>
</tr>
<tr>
<td>stationary</td>
<td>82,000</td>
</tr>
<tr>
<td>pharmaceutic</td>
<td>60,000</td>
</tr>
<tr>
<td>overall</td>
<td>66,000</td>
</tr>
</tbody>
</table>
Ambulatory inequity between need and utilisation

Legend

- ▲ cities (>250,000)
- ambulatory (I)

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Overall inequity between need and utilisation

Legend

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Kernel: adaptive bi-squared parameterisation: N=66,000
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Spatial nonstationarity

The same stimulus provokes a different response in different parts of the study region. (Fotheringham et al. 2002 p. 9)

Because of:

- Sampling variation
- Relationships intrinsically different across space (difference in preferences, supply, or different administrative, political or other contextual effects produce different responses to the same stimuli)
- Model misspecification (missing variables, misspecification of the relationship)
Expanding the model for spatial nonstationarity in treatment

\[ S_i = E N_i(u_i, v_i) + e_i \quad I \quad S = \beta(u_i, v_i) \cdot X + E \]

\[ \hat{\beta}(u_j, v_j) = (X'W(u_j, v_j)X)^{-1}X'S \]

- We treat each disease as treatment for spatial varying utilization.
Concluding Remarks

- Using distances instead of zones helps to address MAUP.
  - Relevant spatial structures could be found and measured.
  - Windfall gains of supply could include in the mapping.
  - Treatment effects of diseases vary up to 0.5% of the total utilisation which could be over 100 Euro per capita.
- The common definition of administrative zones is far to determinate for analysing regional differences in health care utilisation.
  - Regional effect going to be lost, as we assume independent observations for each zone.
- The definition of diseases could be too conservative in the RSCS, as we see spatial clustering which could come up from unobserved diseases and deprivation.
References


pharmacy inequity between need and utilisation

Legend

- cities (>250,000)
- pharmacy

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Examples of MAUP / standardised health care costs and coverage ratios
The Multiple Area Unit Problem (MAUP)

Supplier-induced demand

\[ EV(\beta) = \frac{(X'G'WGX)}{X'WX} = f(G) \]
The Yule-Simpson-effect

\[
E[Y_{\text{red}} | X = x, Z = z] = E[Y_{\text{blue}} | X = x, Z = z]
\]

\[
E[Y_{\text{red}} | X = x] \neq E[Y_{\text{blue}} | X = x]
\]