Geographical Mobility of Patients by Types of Health Care Institutions and Implication on Medical Zoning Policy

Japan Health Economics Association
at Hosei University
September/18/2009

Haruko Noguchi & Nobuyuki Izumida
(h.noguchi@ipss.go.jp)
National Institute of Population and Social Security Research
Overall backgrounds

- Major characteristics of Japanese medical care
  - Universal Coverage
  - Free access to medical facilities

- Differential in accessibility to medical care
  - Profitable urban versus non-profitable local areas

- Crisis of Public hospitals
  - Providing medical care in the depopulated local areas
  - Financial difficulties
  - Acceleration of the unbalanced allocation
  - Serious damage to the public health in the local area

- Medical zoning (Iryo-ken)
  - Several neighboring municipalities are legally integrated as a “medical zoning (or sphere)” to serve the medical needs of the entire population in the region, which is geographically larger than a municipality and smaller than a prefecture.
  - Medical zoning seems to be established mainly by supply-side conditions (not demand-side ones, e.g., patient mobility)
Key questions

- Does uneven allocation of medical resources influence a patient’s geographical mobility and medical expense?
  - Collaborating with a depopulated town, Nakatonbetsu, Hokkaido, Japan

- Is medical zoning policy consistent to patients’ geographical mobility in Nakatonbetsu town?
  - Geographical Information System (Quasi-GIS analyses)

- Increase or decrease in medical expense without the public hospital in Nakatonbetsu?
  - Simple simulation
Where is Nakatonbetsu-town?

- A depopulated small town, “Nakatonbetsu” located in very northern part of Hokkaido, Japan
- 2,289 residents in 2005 census (approximately half of population is insured by the NHI)
- 29.1% of residents are 65+
Estimation strategy

**1\(^{st}\) stage**
- Travel distance function (a patient’s geographical mobility): estimating the effects of the intensity of medical resources within various municipals on a travel distance (km) from a patient’s home to medical facilities

**2\(^{nd}\) stage**
- Demand function: regressing a patient’s demand for medical care (length of hospital stay for inpatient care, number of visits for outpatient care, and medical expenses) on the estimated travel distance estimated from the 1\(^{st}\) stage

**Instrumental variables (IVs)**
- Distance and direction (azimuth: 0° as north and 180° as south) from only one public hospital in Nakatonbetsu district to a patient’s home, supposing that patients’ homes are randomly located, regardless their demand for medical care
- Hypotheses: (1) the farther IV distance, the wider patient mobility; (2) for the direction, unknown (?)
- Three types of regressions are run separately for (1) inpatients-only, (2) outpatients-only, and (3) both inpatients and outpatients, adjusted for the intensity of medical resources and patients’ characteristics
Econometric specifications: 2SLS with IVs

1\textsuperscript{st} stage  
\[ d = Z\pi + \nu \]

2\textsuperscript{nd} stage  
\[ \hat{d} = (Z'Z)^{-1}Z'd \]

where

\[ d = \text{Travel distance from a patient’s home to a hospital in a straight line (km)} \]
\[ \hat{d} = \text{Estimated travel distance from a patient’s home to a hospital (km)} \]
\[ Z = \text{Patient’s characteristics, the intensity of medical resources within various municipals (X), and } r, \theta \text{ as IVs} \]
\[ r, \theta = \text{Distance and azimuth from a patient’s home to the public hospital in Nakatonbetsu town in a straight line (km), supposing a patient’s physical address is randomly allocated in Nakatonbetsu} \]
\[ y = \text{Patient’s demand for medical care (length of hospital stay, number of visits, and medical expense)} \]
\[ X = \text{Patient’s characteristics (age, sex, low income, chronic status, and diagnosed diseases), the intensity of medical resources within various municipals (explained in the “Data” section), and year dummy} \]
\[ \pi, \beta = \text{Parameters to be estimated} \]
\[ \nu, \epsilon = \text{Residuals from 1\textsuperscript{st} and 2\textsuperscript{nd} stage estimations, respectively} \]

\begin{itemize}
  \item Validity of IV:
  \[ E(\epsilon \mid r) = 0 \quad \text{and} \quad E(d \mid r) \neq E(d) \]
  \[ E(\epsilon \mid \theta) = 0 \quad \text{and} \quad E(d \mid \theta) \neq E(d) \]
\end{itemize}
Travel distance and opportunity costs

- A travel distance will be positively correlated to patient’s opportunity costs for demanding both inpatient and outpatient care
  - Shorten length of hospital stay (LHS)
  - Decrease number of hospital visits (HV)
  - Increase medical expense per day (ME)

\[
\begin{align*}
\text{Rate of changes in LHS/HV} & = \text{Rate of changes in ME} \\
& \Rightarrow \text{Total ME} \\
\end{align*}
\]

- Cannot identify patient-oriented/supplier induced demand, because this study does not control for changes in the # of suppliers (or any other environmental change) within municipal areas during the observation period.
Data: Two data sets are merged

- **Micro-level data on monthly medical claims**: April/1/2003-March/31/2007 (60 months) for entire inpatients and outpatients insured by the National Health Insurance (NHI) living in Nakatonbetsu-town, Hokkaido Japan
  - Exclusion criteria: pharmaceutical (N=19,196), dental (N=5,338), acupuncture/moxibustion and chiropractic (N=1,209) services, and samples with missing variables necessary for the analyses (N=27,467) are excluded out of 84,364 records as a total for 60 months
  - # of inpatient records only: 638
  - # of outpatient records only: 29,187
  - # of both inpatients and outpatient records: 1,329

- **Municipal-level intensity of medical resources**: calculated based on facility-based data - WAMNET (the website of Welfare and Medical Service Agency)
  - # of beds and physicians per 0.1 million pop;
  - # of intensive care unit (ICU) and/or coronary care unit (CCU); and
  - Create mean “intensity score” of each municipal for (1) clinical departments, (2) various checkups, (3) rehabilitation/therapy, and (4) surgical operation, using principal component analysis
Deciles of population and allocation of medical facilities in Hokkaido

Soya Medical Zone

Kamikawa-Hokubu Medical Zone

Kamikawa-Chubu Medical Zone

Nakatonbetsu

1070 - 3003
3004 - 5239
5240 - 8392
8393 - 13431
13432 - 21852
21853 - 37066
37067 - 67614
67615 - 142154
142155 - 209425
209426 - 351818

Hospital>= 20 beds
Clinics<20 beds

Deciles of population and allocation of medical facilities in Hokkaido

Soya Medical Zone

Kamikawa-Hokubu Medical Zone

Kamikawa-Chubu Medical Zone

Nakatonbetsu

1070 - 3003
3004 - 5239
5240 - 8392
8393 - 13431
13432 - 21852
21853 - 37066
37067 - 67614
67615 - 142154
142155 - 209425
209426 - 351818

Hospital>= 20 beds
Clinics<20 beds

Deciles of population and allocation of medical facilities in Hokkaido

Soya Medical Zone

Kamikawa-Hokubu Medical Zone

Kamikawa-Chubu Medical Zone

Nakatonbetsu

1070 - 3003
3004 - 5239
5240 - 8392
8393 - 13431
13432 - 21852
21853 - 37066
37067 - 67614
67615 - 142154
142155 - 209425
209426 - 351818

Hospital>= 20 beds
Clinics<20 beds
Deciles of rates of population 65+ and allocation of medical facilities in Hokkaido

Soya Medical Zone

Kamikawa-Hokubu Medical Zone

Kamikawa-Chubu Medical Zone

Nakatonbetsu

Hospital >= 20 beds
Clinics < 20 beds

- 14.7% - 18.3%
- 18.4% - 20.8%
- 20.9% - 23.2%
- 23.3% - 25.1%
- 25.2% - 26.7%
- 26.8% - 28.4%
- 28.5% - 30.3%
- 30.4% - 32.4%
- 32.5% - 35.2%
- 35.3% - 39.7%

0 40 80 120 160 200 240 kilometers
Quintiles of medical intensity based on principal component analysis and allocation of medical facilities in Hokkaido

Soya Medical Zone

Kamikawa-Hokubu Medical Zone

Kamikawa-Chubu Medical Zone

Nakatonbetsu

Hospital >= 20 beds
Clinics < 20 beds

-0.652 - 0.273
-0.272 - 0.292
0.293 - 1.205
1.206 - 3.368
3.369 - 6.199
Efficiency rates of medical zoning by type of service, patient physical address, and location of medical facility

<table>
<thead>
<tr>
<th>Location of medical facility</th>
<th>Total (N=638)</th>
<th></th>
<th>Total (N=29,187)</th>
<th></th>
<th>Total (N=1,329)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nakaton district</td>
<td>Outside of Nakaton district</td>
<td>Nakaton district</td>
<td>Outside of Nakaton district</td>
<td>Nakaton district</td>
<td>Outside of Nakaton district</td>
</tr>
<tr>
<td>A. Within Nakatonbetsu</td>
<td>8,843</td>
<td>6,931</td>
<td>47,211</td>
<td>16,167</td>
<td>14,065</td>
<td>3,668</td>
</tr>
<tr>
<td>B. Outside of Nakatonbetsu</td>
<td>17,626</td>
<td>9,884</td>
<td>14,574</td>
<td>7,211</td>
<td>28,798</td>
<td>9,745</td>
</tr>
<tr>
<td>B-1. Soya medical zone</td>
<td>1,243</td>
<td>64</td>
<td>844</td>
<td>447</td>
<td>593</td>
<td>297</td>
</tr>
<tr>
<td>B-2. Kamikawa-Chubu medical zone</td>
<td>8,423</td>
<td>5,459</td>
<td>1,449</td>
<td>1,730</td>
<td>9,295</td>
<td>5,525</td>
</tr>
<tr>
<td>B-3. Kamikawa-Hokubu medical zone</td>
<td>6,549</td>
<td>3,519</td>
<td>3,950</td>
<td>4,130</td>
<td>8,534</td>
<td>3,692</td>
</tr>
<tr>
<td>B-4. Other area</td>
<td>1,411</td>
<td>841</td>
<td>2,471</td>
<td>1,107</td>
<td>6,376</td>
<td>4,389</td>
</tr>
<tr>
<td>C. Total</td>
<td>26,469</td>
<td>16,815</td>
<td>61,785</td>
<td>23,531</td>
<td>42,863</td>
<td>13,413</td>
</tr>
</tbody>
</table>

(1) Medical expenditure (unit: 1,000 points)

- A/C: 33.4% 41.2% 19.8% 76.4% 81.2% 68.7% 32.8% 35.3% 27.3%
- B/C: 66.6% 58.8% 80.2% 23.6% 18.8% 31.3% 67.2% 64.7% 72.7%
- B-1. A+(B-1)/C: 38.1% 41.6% 32.0% 77.8% 82.3% 70.4% 34.2% 36.3% 29.6%
- B-2. B-2/C: 31.8% 32.5% 30.7% 5.1% 3.8% 7.4% 21.7% 18.8% 28.1%
- B-3. B-3/C: 24.7% 20.9% 31.4% 13.1% 10.3% 17.6% 29.2% 30.0% 27.5%

(2) Efficiency rates of medical zoning

For “inpatients”, “outpatients”, and “both in/out patients within a month”, 33%, 76%, and 33% are utilizing medical service provided by the public hospital within Nakatonbetsu, which indicates that patients tend to behave differently between inpatient and outpatient care.

For “outpatient” care, the “accessibility” would be one of the most significant factor to determine travel distance to hospitals.

As regards patients receiving care outside of the town, they are less likely to receive care within “Soya” Medical zone (in which Nakatonbetsu is located), because efficiency rates between Nakatonbetsu and Soya medical zone (including Nakatonbetsu) are almost identical for any type of care (for instance, 33% (Nakatonbetsu) and 38% (Soya) for inpatients; 76% (Nakatonbetsu) and 79% (Soya) for outpatients).

For “inpatients” outside of Nakatonbetsu, patients tend to go to “Kamikawa-Chubu” medical zone (32%), which is located in southern part. Also, for “outpatients” and “both in/out patients” outside of Nakatonbetsu, they are more likely to go to “Kamikawa Hokubu” medical zone (13% and 30%), which is also located in southern part.
Basic statistics by type of service

<table>
<thead>
<tr>
<th></th>
<th>Inpatients records only (N=688)</th>
<th>Outpatient records only (N=29,187)</th>
<th>Both in- and outpatients (N=1,329)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Frequency of service use per month (length of stay for inpatients/ Number of visits for outpatients) and medical expenditure per month and per day.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency of service use</td>
<td>27.43 (9.66)</td>
<td>2.60 (2.33)</td>
<td>15.54 (9.82)</td>
</tr>
<tr>
<td>Expenditure per day (unit: point)</td>
<td>1,639 (1,476)</td>
<td>904 (747)</td>
<td>2,136 (1,961)</td>
</tr>
<tr>
<td>Total expenditure per month (unit: point)</td>
<td>41,488 (37,848)</td>
<td>2,117 (2,213)</td>
<td>32,252 (38,235)</td>
</tr>
<tr>
<td><strong>B. Patient characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living in Nakatonbetsu District (=1)</td>
<td>0.68 (12.81)</td>
<td>0.59 (10.87)</td>
<td>0.67 (12.00)</td>
</tr>
<tr>
<td>Female (=1)</td>
<td>0.49 (2.47)</td>
<td>0.58 (2.56)</td>
<td>0.59 (2.59)</td>
</tr>
<tr>
<td>Age</td>
<td>75.34 (12.21)</td>
<td>74.17 (18.07)</td>
<td>78.80 (12.09)</td>
</tr>
<tr>
<td># of Household members insured by NHI</td>
<td>2.40 (1.71)</td>
<td>3.63 (2.47)</td>
<td>4.98 (2.56)</td>
</tr>
<tr>
<td>Tax-exempt household (=1)</td>
<td>0.74 (1.71)</td>
<td>0.54 (2.47)</td>
<td>0.58 (2.56)</td>
</tr>
<tr>
<td>Length of being treated &gt; 0/ days (Median) (=1)</td>
<td>0.47 (0.47)</td>
<td>0.60 (0.60)</td>
<td>0.48 (0.48)</td>
</tr>
<tr>
<td><strong>C. Municipal-level intensity of medical resources, where a patient received medical service</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel distance from a patient’s home to a hospital in a straight line (km)</td>
<td>38.61 (63.07)</td>
<td>20.69 (38.72)</td>
<td>43.51 (50.03)</td>
</tr>
<tr>
<td># of beds per 0.1 million pop</td>
<td>2,199 (362)</td>
<td>2,086 (122)</td>
<td>2,182 (122)</td>
</tr>
<tr>
<td># of physicians per 0.1 million pop</td>
<td>189 (122)</td>
<td>124 (79)</td>
<td>162 (104)</td>
</tr>
<tr>
<td># of intensive care unit (ICU) and/or coronary care unit (CCU)</td>
<td>0.29 (0.51)</td>
<td>0.06 (0.25)</td>
<td>0.17 (0.38)</td>
</tr>
<tr>
<td>Intensity score for clinical departments</td>
<td>0.34 (1.42)</td>
<td>-0.61 (0.93)</td>
<td>-0.09 (1.02)</td>
</tr>
<tr>
<td>Intensity score for various checkups</td>
<td>0.84 (1.04)</td>
<td>-0.11 (0.57)</td>
<td>0.23 (0.70)</td>
</tr>
<tr>
<td>Intensity score for various rehabilitation/therapy</td>
<td>-0.17 (0.63)</td>
<td>-0.39 (0.48)</td>
<td>-0.24 (0.50)</td>
</tr>
<tr>
<td>Intensity score for various surgical operation</td>
<td>0.80 (1.04)</td>
<td>0.22 (0.74)</td>
<td>0.56 (0.77)</td>
</tr>
</tbody>
</table>

For inpatient care,
- Longer travel distance
- More intensive at municipal-level than other type of care
### 1st stage (1): Test statistics of week IVs

<table>
<thead>
<tr>
<th></th>
<th>Inpatients records only</th>
<th>Outpatient records only</th>
<th>Both in- and outpatients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent variable:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel distance from a patient’s home to a hospital in a straight line (km)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>IVs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance from Nakatonbetsu district to a patient home</td>
<td>1.06 ***</td>
<td>0.28 ***</td>
<td>-0.15 ***</td>
</tr>
<tr>
<td>(0.19)</td>
<td>(0.02)</td>
<td>(0.13)</td>
<td></td>
</tr>
<tr>
<td>Direction from Nakatonbetsu district to a patient home</td>
<td>-0.03 ***</td>
<td>0.004 ***</td>
<td>0.02 ***</td>
</tr>
<tr>
<td>(0.01)</td>
<td>(0.001)</td>
<td>(0.01)</td>
<td></td>
</tr>
<tr>
<td><strong>Test statistics of week IV</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anderson’s CC LM statistic</td>
<td>29.18</td>
<td>759.82</td>
<td>34.58</td>
</tr>
<tr>
<td>p-value</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Cragg-Donald Wald F statistic</td>
<td>14.83</td>
<td>389.80</td>
<td>17.49</td>
</tr>
<tr>
<td><strong>Test statistic of model</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>929.44</td>
<td>20861.17</td>
<td>1020.94</td>
</tr>
<tr>
<td>Centered R2</td>
<td>0.96</td>
<td>0.93</td>
<td>0.94</td>
</tr>
<tr>
<td>Uncentered R2</td>
<td>0.98</td>
<td>0.95</td>
<td>0.96</td>
</tr>
<tr>
<td>Number of observation</td>
<td>638</td>
<td>29,187</td>
<td>1,329</td>
</tr>
</tbody>
</table>

Coefficients are significant at ***1%, **5%, *10%-level.

- For both “inpatient” and “outpatient” care, the distance from Nakatonbetsu district to a patient home has a significant positive effects on patient mobility. However, this is not a case for those receiving both in- and outpatient care within the same month.
- For “inpatient” care, the direction has a significant negative effects on travel distance, meaning that it tends to be shorter for patients living in southern part to Nakatonbetsu district. The results are reversed for “outpatient” and “both in/outpatient “ care.
- Test statistics of week IV shows that the null hypothesis of “IVs are week” can be rejected. The F and R2 do seem to be large enough to explain the validity of these IVs.
1\textsuperscript{st} stage (2): Impacts of patient characteristics and municipal-level intensity of medical resources

<table>
<thead>
<tr>
<th>Dependent variable: Travel distance from a patient’s home to a hospital in a straight line (km)</th>
<th>Inpatients records only</th>
<th>Outpatient records only</th>
<th>Both in- and outpatients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female (=1)</td>
<td>3.11 ( (***) )</td>
<td>0.18 ( (*) )</td>
<td>3.68 ( (***) )</td>
</tr>
<tr>
<td>Age</td>
<td>-0.05 ( (0.05) )</td>
<td>0.05 ( (***) )</td>
<td>-0.08 ( (***) )</td>
</tr>
<tr>
<td># of Household members insured by NHI</td>
<td>0.75 ( (0.33) )</td>
<td>0.01 ( (0.03) )</td>
<td>-0.06 ( (0.16) )</td>
</tr>
<tr>
<td>Tax-exempt household (=1)</td>
<td>-1.33 ( (1.28) )</td>
<td>-0.39 ( (0.13) )</td>
<td>1.88 ( (***) )</td>
</tr>
<tr>
<td>Length of being treated &gt; 90 days (Median) (=1)</td>
<td>0.49 ( (1.06) )</td>
<td>-1.50 ( (1.05) )</td>
<td>-3.11 ( (***) )</td>
</tr>
</tbody>
</table>

C. Municipal-level intensity of medical resources, where a patient received medical service

| # of beds per 0.1 million pop | 0.02 \( (***) \) | 0.02 \( (***) \) | 0.01 \( (***) \) |
| # of physicians per 0.1 million pop | -0.15 \( (0.01) \) | -0.15 \( (0.00) \) | -0.14 \( (0.01) \) |
| # of intensive care unit (ICU) and/or coronary care unit | 75.45 \( (***) \) | 97.69 \( (***) \) | 93.82 \( (***) \) |
| Intensity score for clinical departments | 118.87 \( (***) \) | 119.68 \( (***) \) | 116.76 \( (***) \) |
| Intensity score for various checkups | -103.58 \( (***) \) | -95.73 \( (***) \) | -108.17 \( (***) \) |
| Intensity score for various rehabilitation/therapy | -65.38 \( (***) \) | -34.05 \( (***) \) | -48.07 \( (***) \) |
| Intensity score for various surgical operation | 1.32 \( (2.24) \) | -26.88 \( (***) \) | -7.24 \( (***) \) |

Coefficients are significant at \( ***1\% \), \( **5\% \), \( *10\%-level \).
Estimated geographical mobility of patients based on 1st stage of regression

- For any type of care, patients tend to receive care in municipals located in southern part to Nakatonbetsu, which are consistent to results of basic stats.
- There is a possibility that “Soya” medical zone is inconsistent to patient behavior for Nakatonbetsu-town.

Inpatients records only:
95% confidential interval=(9.6km, 110.8km)

Outpatients records only:
95% confidential interval=(23.1km, 31.7km)

Both in/out patients records:
95% confidential interval=(24.2km, 55.8km)
2nd Stage: Impacts of patient geographical mobility on demand for medical care by 2SLS

- A longer travel distance is more likely to:
  - decrease number of frequency of service use for “outpatients” and “both in/outpatients” records
  - increase expenditure per day (or per visit) for “outpatients” and “both in/outpatients” records
  - As results, decrease in total expenditure per month only for “outpatients” records

Rate of changes in LHS/HV > Rate of changes in ME ⇒ Total ME ↓

- No significant impacts at all for inpatient care
- Some regressions cannot reject test statistics for overidentification (which is good, in this case), but that is not the case for all regressions. Therefore, IVs are not robust enough...
How far patients go if the public hospital does not exist within the town?: Simulation I for inpatients records only

Current
95% confidential interval=(9.6km, 110.8km)
Total annual expenditure = about 53 million yen

Simulation without the public hospital
95% confidential interval=(24.1km, 208.0km)
Total annual expenditure = about 49 million yen
How far patients go if the public hospital does not exist within the town?:
Simulation II for outpatients records only

Current
95% confidential interval = (23.1 km, 31.7 km)
Total annual expenditure = about 120 million yen

Simulation without the public hospital
95% confidential interval = (74.8 km, 99.5 km)
Total annual expenditure = about 120 million yen
How far patients go if the public hospital does not exist within the town?:
Simulation III for both in- and outpatients records

Current
95% confidential interval = (24.2 km, 55.8 km)
Total annual expenditure = about 86 million yen

Simulation without the public hospital
95% confidential interval = (57.1 km, 139.0 km)
Total annual expenditure = about 82 million yen
Efficiency rate of “Soya” Medical Zone is not necessarily lower than other parts of Japan. For example, compared three prefectures (Chiba, Nagano, and Fukuoka) evaluated by Izumida (2000), the efficiency rate of “Soya” Medical Zone is about the same level or higher than rural areas of these three prefectures (of course, it is much lower than urban areas, which are about 80-90%).

However, the validity of “Soya” Medical Zone has achieved solely because of high utilization rates of the public hospital within Nakatonbetsu-town. Patients who receive medical care outside of Nakatonbetsu are more likely to go to other Medical zones such as “Kamikawa-Hokubu” and “Kamikawa-Chubu”, which are located in southern part to Nakatonbetsu-town.
Geographical mobility of patients in Nakatonbetsu would depend on municipal-level intensity of medical resources, such as # of beds, # of ICU/CCU, and “intensity score” of clinical departments. However, variables indicating the intensity might be highly correlated with each other, which would lead multicollinearity. Therefore, results of other intensity variables seem to be reversed to what we expected.

As regards patient characteristics, the results vary by type of care. For “inpatients records only”, old age and # of family have a significant positive impacts on patient travel distance. For “outpatients” only and “both in/outpatients”, old age, tax-exempt household (=low-income), and presence of chronic conditions tend to shorten patient travel distance.

Therefore, for daily-based outpatient care, longer travel distance might make opportunity costs higher, for elderly patients, low-income households, and those with chronic health status.
Based on simple simulation analyses based on quasi-GIS, patients in Nakatonbetsu tend to receive care in municipals located in southern part to Nakatonbetsu, when they do not go the public hospital within the town.

Therefore, there is a possibility that “Soya” medical zone is inconsistent to patient behavior for Nakatonbetsu, adjusting for the demand-side conditions.

Medical zoning is established mainly in terms of considering supply-side conditions. For the functions/roles of municipals as insurers, the inconsistency between medical zoning and patient geographical mobility (based on “free-access”) must be causing “inefficiency”, which should be modified due to severe financial restrictions of each municipal, in particular, rural areas like Nakatonbetsu, in Japan.

Further empirical research are required for examining the consistency of medical zoning and geographical mobility of patients, from both supply- and demand-sides.
If the public hospital does not exist in Nakatonbetsu-town:

- Travel distances will be lengthening from 60 km to 116km for inpatients; from 20km to 87km for outpatients; and from 44km to 98km for both in/out patients, in average, if the public hospital does not exist in Nakatonbetsu.

- On the other hand, the annual medical expenditure (only for inpatient and outpatient care) will slightly be decreasing as a whole. Therefore, financial difficulties of a municipal may possibly be improved.

- However, longer travel distance might be risky for population health status, in particular, for elderly patients, low-income households, and those with chronic health status.
Further research required

- **Statistical challenges (causality between geographical mobility of patients and demand for health care):**
  - Finding more appropriate IVs
  - Obtaining/Finding opportunities of “Natural Experiment”
  - Possibility of non-parametric strategy

- **Policy challenges**
  - Applying this type of GIS analysis to examine the data from other part of Japan, in order to validate the consistency of medical zoning and patient behavior
  - Considering the validity of medical zoning from both supply- and demand-sides, and improving the functions/roles of each municipal as an insurer more efficient