Hazard Mapping Ocean Risk of Tsunami and Flood: Case of Southern Hokkaido

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DRAFT, DO NOT CITE
Motivations

• Disaster risk reduction (DRR) is a vital scheme for Blue Economy, a more resilient society will be essential for sustainable development.

• Ocean related natural disasters, such as Tsunami should be tackled with cautions, the effective plan for resilience investment is desirable.

• Evidence-based and visualized approach for recovery would assist policy makers to allocate resources or call for financing options:
  
  ➢ Huang & Hosoe (2016, 2017): Recovery process for a compound disaster of earthquake and nuclear disaster in Northern Taiwan;

  ➢ Huang & Masuda (Forthcoming): The global supply chains disruptions by disasters: Cases of Japan, Taiwan and Thailand;

  ➢ Huang, Tanaka & Yoshioka (Forthcoming): Disaster risk financing by examining Cost-effective industrial policy for ASEAN countries
### Visualized disaster impact and policy simulations

- Detailed and precise estimate for city-based analysis would be vital for disaster risk reduction (DRR) plans.
- Data: **Japan 2015 Input-Output Table**, damages estimated by Cabinet Office.

| Source: Developed by authors based on Cabinet Office of Japan (2017) |

<table>
<thead>
<tr>
<th>City</th>
<th>3-yr PRO</th>
<th>5-yr PRO</th>
<th>7-yr PRO</th>
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| Change of output and price (%) |

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**Table**: Overview of damage estimates across different regions and sectors.
Outlines

• **Methodology of estimating tsunami damage from Hazard Map**
  ➢ GIS Analysis with supplementary census data (on industry unit/location)

• **Input-output analysis**
  ➢ The interdependence of blue economy related sectors in a regional City

• **Recursive CGE model for policy simulations**
  ➢ Identify the sectoral vulnerabilities
  ➢ Estimate the costs required for recovery and social welfare analysis
  ➢ Provide policy recommendations for DRR

• **Policy implications**
South of Hokkaido - Hakodate City

- Major city in Southern Hokkaido.
- Famous for Kelp, Squid and Tourism.
- The most attractive city in Japan (2018).

- Area: 677.8 km²
- Population: 256,917

- Downtown
Flood damage of Tsunami in Hakodate-city

- Hakodate City is highly exposed to Tsunamis (eg. 1960, 1968, 2011).
- 12 million USD losses in 2011 by Tsunami.
- The large-scale earthquake or tsunami can happen within 30 years with relatively high probability nearside Hakodate City.
- Effective disaster risk reduction policy desirable.
The Tsunami hazard map of downtown Hakodate City

- The fishery morning market may face 4-7m tsunami (yellow area).
- Other major streets may be flooded by 1-4m (blue area).
- The impact would be devastating.
The flow of estimation of expected damage and formulation of disaster risk reduction plans

1. Estimation of lost Capitals and Labor by Tsunami
2. Analysis of the ripple effect in the regional economy caused by lost Capitals and Labor
3. Simulation of sectoral disaster impact its recovery process

GIS
Input-Output analysis
CGE model
Process to estimate capital and labor losses

① The number of offices and employees by street or district

② Tsunami hazard map: The average height of flooding area

③ The land usage map: Identify the geographical location of offices.

④ The rate of building area covered by Tsunami (② + ③):
   To estimate the ratio of office area covered by Tsunami.

⑤ The ratio of buildings(wooden or non-wooden) in Hakodate city:
   To categorize damages by type of buildings

⑥ Tsunami damage classifications:
   To categorize damages by height and types of buildings
The information of the number of offices and employees by street or district.

- Each point (211) has the number of offices and labor of 97 industries in each district in 2016.
- It does not include geographic information of offices in each district.
- It can contain estimated locational data by combining with ③ “land usage map”.
② Tsunami hazard map

- It was published by Hokkaido local government in 2012.
- It assumes maximum earthquake and max height of Tsunami by 10 meters interval.
- 189,660 samples.
- Min: 0.01m
- Max: 15.75m
- Ave: 3.1m
- SD: 1.5m
③ The land usage map

- Published by Ministry of Land, Infrastructure, Transport and Tourism in 2014.
- It categorizes the land use using satellite images.
- “Land for building” where offices accumulates can be assumed to contain all offices.
The rate of building area covered by Tsunami (② + ③)

- Here we made the buildings area covered by Tsunami.
- Calculated the average coverage rate of Tsunami in buildings area in each district.
- By multiplying with ①, the estimate number of offices damaged by Tsunami can be estimated.
The ratio of buildings in Hakodate city (wooden or non-wooden)

- Damage to buildings differs by the type of buildings.
- There is no data of the number of buildings by types in each street and district.
- The rate of them in Hakodate city was used as estimation rate.

<table>
<thead>
<tr>
<th></th>
<th>Number of existing buildings</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wooden</td>
<td>98,925</td>
<td>79.2%</td>
</tr>
<tr>
<td>Non-Wooden</td>
<td>25,960</td>
<td>20.8%</td>
</tr>
</tbody>
</table>

Authors calculated from the summary of tax revenue in Hakodate city (2014)
# Tsunami damage classifications

<table>
<thead>
<tr>
<th>Damage Category</th>
<th>Flooded Height (H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wooden Buildings</td>
<td>Non-Wooden Buildings</td>
</tr>
<tr>
<td>Fully collapse</td>
<td>$2.0m \leq H$</td>
</tr>
<tr>
<td>Half collapse</td>
<td>$1.0m \leq H &lt; 2.0m$</td>
</tr>
<tr>
<td>High flooding</td>
<td>$0.5m \leq H &lt; 1.0m$</td>
</tr>
<tr>
<td>Low flooding</td>
<td>$0.0m &lt; H &lt; 0.5m$</td>
</tr>
</tbody>
</table>

Source: Hakodate City (2012)

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*Estimated by authors*
## Data for policy simulations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Sector</th>
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<tbody>
<tr>
<td>AGR</td>
<td>Agriculture, Forest and mining</td>
</tr>
<tr>
<td>SWD*</td>
<td>Kelp</td>
</tr>
<tr>
<td>NEF*</td>
<td>Fixed Net-fishery</td>
</tr>
<tr>
<td>SQI*</td>
<td>Squid</td>
</tr>
<tr>
<td>FIS*</td>
<td>Other fishery</td>
</tr>
<tr>
<td>PRO*</td>
<td>Food processing</td>
</tr>
<tr>
<td>TEX</td>
<td>Texile</td>
</tr>
<tr>
<td>PET</td>
<td>Petroleum &amp; chemical</td>
</tr>
<tr>
<td>MAE</td>
<td>Metal &amp; machinery</td>
</tr>
<tr>
<td>MDU</td>
<td>Education &amp; medical service</td>
</tr>
<tr>
<td>CON</td>
<td>Construction</td>
</tr>
<tr>
<td>ELY</td>
<td>Electricity</td>
</tr>
<tr>
<td>COM</td>
<td>Commerce &amp; financing</td>
</tr>
<tr>
<td>TRS</td>
<td>Transportation &amp; communication</td>
</tr>
<tr>
<td>SRV</td>
<td>Public service</td>
</tr>
<tr>
<td>REC*</td>
<td>Recreation (Restaurant &amp; hotel)</td>
</tr>
<tr>
<td>Labor</td>
<td>Labor endowment</td>
</tr>
</tbody>
</table>

*Blue economy related sectors

- The 2005 input-output table of Hakodate City (detailed categorized in fishery and recreation sectors) (Furuya, Kamikawa, Kitahara, Asakawa, Nakaizumi & Nagano, 2006)

- Estimated the loss of offices & employees in 97 industries by the max height of Tsunami in each region.

- Combining with I-0 Table, we calculate effects of those losses in the Hakodate regional economy.
Input-Output Analysis: The economic interdependence

Economic effect [%]

Economic effect [million JPY]

Direct impact  Labor impact  Capital impact
Model Structure

Household Utility (UU)

Household Consumption ($X_i^P$)

Government Consumption ($X_i^G$)

Investment ($X_i^I$)

Intermediate uses ($\Sigma_j X_{i,j}$)

Composite good ($Q_i$)

Imports ($M_i$)

Domestic good ($D_i$)

Exports ($E_i$)

Composite factor ($Y_i$)

Gross domestic output ($Z_{i,j}$)

Intermediate Inputs ($X_{i,j}$)

Labor ($F_{LAB,i,j}$)

Capital-use Subsidy ($F_{CAP,i,j}$)

Source: Revised by authors based on Huang & Hosoe (2016, 2017)
Assumed sectoral damage by tsunami

*Due to data limitation, the damage on NEF and FIS are assumed equivalent with SWD and SQI respectively*
Scenarios for policy simulations

• 10-year recovery policy for blue economy related sectors:
  ➢ SWD (Kelp), NEF (Fixed Net-fishery), SQI (Squid), FIS (other fishery), PRO (food processing [agriculture & fishery]), REC (recreation [restaurant & hotel])

• Recursive modelling assumptions:
  ➢ Capital factor: immobile [could only be increased by investment]
  ➢ Labor factor: mobile, could recover 75% every year, fully recover in 5-th year.

• Recovery policy:
  ➢ Capital-use subsidy: (to add back the damaged capital stock)
  ➢ Target year: to resume the output level as before the disaster in the 11th year.
Kelp: could not recover even with subsidy
(capital-use subsidy rate: 31%)
Fishery: Could only recover by 20%  
(capital-use subsidy rate: 42%)
Recreation: Recovery requires massive support
(capital-use subsidy rate: 33.5%)
Fixed-net Fishery: Hardly recover, with social benefits
(capital-use subsidy rate: 34%)
Squid: The symbolic industry hardly recover, but with social benefit (capital-use subsidy rate: 30%)
Food processing: Massive cost, not fully recover, significant social benefit (capital-use subsidy rate: 47.2%)
Conclusion & Policy Implications

• The **CGE model**, together with **hazard map** and **industry census** could visualize and quantify the disaster impact with DRR recommendations.

• The aquaculture sectors: **Fishery (FIS)**, **Squid (SQI)**, **Kelp (SWD)** and **Fixed-net Fishery (NEF)** are **extremely vulnerable** and could not recover within the Hakodate’s capacity, **require special measures/mechanism** to reduce disaster risk.

• **Food processing sector (PRO)** requires huge support to recover, but could generate notable social benefits (with increase of **SQI**), such sector **should be promoted**.

• More scenarios of **DRR measures** (eg. **Dyke construction, building reinforcement**) should be made available, awareness and DRR could be quantified.

• **Investing in resilience could ensure prosperous blue economy**: The simulation results could also provide city and regional based with development potential for **Blue Finance**.
Disaster risk reduction is everyone’s responsibility
Thank You.