How will the Difference in People’s Network Structure Have Impact on Japanese Public Pension System?

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Today’s Talk

1. Background

2. Basics
   (1) Basic Words and Definitions
   (2) Implemented Network Models
   (3) Agent-to-Agent Interactions

3. Simulation Results
   (1) Network Indices
   (2) Network Structures and Real People’s Network
   (3) Each Agent Role and Pension Premium Fund

4. Conclusion and Future Works
Background

The current situation surrounding Japanese public pension system

✓ Growing steadily worse…

<Causes>

- The aggravation of the financial condition of the public pension system caused by Japanese rapidly aging population.

- Many people’s pension account numbers do not correspond to public pension record (about 50 million!).

- In a fairly recent past, Japanese government release a tentative estimation that shows the future pension benefit level will be lower than the initial estimation.

<Results>

- Increase the public’s distrust in public pension system itself.

- Generate even more public’s distrust in public pension system itself.

There is no simulation model that addresses the change in people’s mood and attitude toward Japanese public pension system.
Background

- Explore the relationship between people’s network structure and instability of the pension system.

- Clarifying how spreading people’s distrust in Japanese public pension system through their network would have effect on pension premium fund.

- We created our model with care and attention for economical, sociological and network theoretical points.

1. Implement various networks.
2. Analyze the mechanism of agent-to-agent network using various network indices.
3. Weigh a network model against the other one from the standpoint of its adaptation to the reality.
4. Pick up some network models that have good fit with reality and clarify the impact of people’s distrust in public pension system.
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Basic Words and Definitions

Explaining on basic words and giving definitions.

- **Agent** acts as vertex or node in graph theory.
- **Link** is used synonymously with edge in graph theory.
- **Degree** as a concept that considers the number of lines incident with each node in a graph. [e.g. Wassarman & Faust (1994)]
- Final vertex in graph theory as *linked agent*
- Incidence or adjacent in graph theory as *agent’s link* or *agent put a link to the other (each other)* or *agent’s network* or *agent’s relationships*, in some case.
- **Path** has same means as it in graph theory.

Measure the feature of a network in the **average of shortest path**, the **clustering coefficient** and **degree distribution**.

- **Small world phenomenon** as a situation where the average of shortest path is small.
- **Scale freeness** as a situation where the degree distribution has good fit to power law.
Implemented Network Models

- Random Network (RNM)
  - Has a feature that edges between vertices are stochastically-generated.
  - Obtained by adding edges between vertices at random.

- Barabasi-Albert Model (BAM)
  - Network expands continuously by the addition of new vertices
  - New vertices attach preferentially to sites that are already well connected. [Barabasi & Albert (1999)]

- Threshold Model (TRM)
  - All of vertices has weight $w_i (i = 0, 1, \ldots, n)$ and they are distributed according to probability density function $f(x)$

$$f(x) = \begin{cases} \lambda e^{-\lambda x} & (x \geq 0) \\ 0 & (x < 0) \end{cases}$$

where $\lambda$ is a positive constant.

  - If the sum of $w_1$ and $w_2$ exceed or even equal threshold, vertices link with each other.
  - Have small world phenomenon and meet scale freeness according to the condition of parameter.
Implemented Network Models

Each model’s features are summarized as follows.

<table>
<thead>
<tr>
<th>Model</th>
<th>Small World</th>
<th>Scale Free</th>
<th>Cluster</th>
<th>Remarks Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNM</td>
<td>○</td>
<td>×</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>BAM</td>
<td>○</td>
<td>○</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>TRM</td>
<td>△</td>
<td>△</td>
<td>△</td>
<td>According to the Value of Parameter</td>
</tr>
<tr>
<td>Real Network</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
</tr>
</tbody>
</table>
Implemented Network Models

Based on network models in previous slide...

- Implement seven models.
- Each model varies with some factors; (1) the type of network, (2) linked agent, (3) the timing of breaking off agent-to-agent relationships.

<table>
<thead>
<tr>
<th>Model</th>
<th>Group</th>
<th>Linked Agent</th>
<th>The Timing of Breaking off Agent-to-Agent Relationships</th>
<th>Remarks Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>RNM</td>
<td>Same Age Groups</td>
<td>Every 13 steps</td>
<td>20 % of Agents Break their Link</td>
</tr>
<tr>
<td>1</td>
<td>BAM</td>
<td>Same Age Groups</td>
<td>Every 13 steps</td>
<td>20 % of Agents Break their Link</td>
</tr>
<tr>
<td>2</td>
<td>RNM</td>
<td>Different Age Groups</td>
<td>Every 13 steps</td>
<td>20 % of Agents Break their Link</td>
</tr>
<tr>
<td>3</td>
<td>BAM</td>
<td>Different Age Groups</td>
<td>Every 13 steps</td>
<td>Assume that agents drift away from each other</td>
</tr>
<tr>
<td>4</td>
<td>RNM</td>
<td>Different Age Groups</td>
<td>Every 179 steps</td>
<td>Assume that agents drift away from each other</td>
</tr>
<tr>
<td>5</td>
<td>BAM</td>
<td>Different Age Groups</td>
<td>Every 179 steps</td>
<td>#20 % of Agents Break their Link</td>
</tr>
<tr>
<td>6</td>
<td>TRM</td>
<td>Same Age Groups</td>
<td>Every 13 steps</td>
<td>#Combination of Threshold and the exponentially-distributed parameters</td>
</tr>
</tbody>
</table>

The factors that are common to all models...

(Based on Japanese government’s estimation of future population.)
- One-step is defined as one month.
- Agent gets older and they have life expectancy.
- New agents are created in the simulation.
- There are nine age group spaces, (20-24 space, 25-29 space, ..... ,60 over space.)
Agent-to-Agent Interactions

- Each agent has an "attitude score."
- Quantified the degree of subjective opinion about the Japanese public pension system.
- By reference to the DSIT model, especially Morio (2003).
- Each agent's attitude score is changed with...
  - The interaction between agents who have linkage to each other.
  - Each agent makes a decision about whether or not to pay pension premium.

Non-linearly and gradually changed under the influence of the other agent.
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Network Indices

- In the field of network analysis, there are common-used network indices.

<table>
<thead>
<tr>
<th>No.</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Average of Shortest Path</td>
</tr>
<tr>
<td>2</td>
<td>Clustering Coefficient</td>
</tr>
<tr>
<td>3</td>
<td>Betweenness Centrality</td>
</tr>
<tr>
<td>4</td>
<td>Degree Distribution</td>
</tr>
</tbody>
</table>

- We use typical network indices for our analysis.
- Using the average of shortest path, clustering coefficient and degree distribution.
- We can see whether the whole structure of agent’s network have small world phenomenon or meet scale freeness.
- Using betweenness centrality.
- We can also see each agent’s role in the whole structure of agent’s network.
The maximum value of the average of shortest path in each model is a little over 5 points.

In this respect, the whole structure of agent’s network in each model have small world phenomenon.

Moreover, viewed from the average of shortest path, it might be said that all of model fit people’s network in reality.
In the field of network theory, it is said that the clustering coefficient in real people’s network is within the range from 0.1 to 0.7.

As shown in Figure, in Model0, Model2, Model4 and Model6 (theta = 3, lambda = 0.5), the maximum value of the clustering coefficient is within the range from 0.1 to 0.7.

In this sense, four models fit people’s network in reality.
# Degree Distribution

- The agent’s networks that have good fit to power law are in **Model 0, 1, 4 and 5**.
- In Model 6, the absolute values of exponent are not so large in almost all cases.
- They are within the range from 1.5 - 1.75.
- It would be safe to say that degree distribution have good fit for power law.
- The higher the value of lambda is, the lesser the chance for putting a link to the other agent is.
- **However, hub-agents come into existence regardless of the value of lambda.**

<table>
<thead>
<tr>
<th>Model</th>
<th>Step</th>
<th>Regression Formula</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 0</td>
<td>59th Step</td>
<td>$y = 6739x^{-4.2711}$</td>
<td>0.9227</td>
</tr>
<tr>
<td></td>
<td>767th Step</td>
<td>$y = 1750.4x^{-3.3556}$</td>
<td>0.8344</td>
</tr>
<tr>
<td>Model 1</td>
<td>59th Step</td>
<td>$y = 231.75x^{-2.4601}$</td>
<td>0.7865</td>
</tr>
<tr>
<td></td>
<td>767th Step</td>
<td>$y = 115.32x^{-2.1234}$</td>
<td>0.7188</td>
</tr>
<tr>
<td>Model 2</td>
<td>59th Step</td>
<td>$y = 69.183x^{-0.5997}$</td>
<td>0.1109</td>
</tr>
<tr>
<td></td>
<td>767th Step</td>
<td>$y = 22.209x^{-0.0219}$</td>
<td>0.0001</td>
</tr>
<tr>
<td>Model 3</td>
<td>59th Step</td>
<td>$y = 133.14x^{-1.4922}$</td>
<td>0.4572</td>
</tr>
<tr>
<td></td>
<td>767th Step</td>
<td>$y = 44.243x^{-1.03}$</td>
<td>0.2167</td>
</tr>
<tr>
<td>Model 4</td>
<td>59th Step</td>
<td>$y = 876.49x^{-2.273}$</td>
<td>0.8733</td>
</tr>
<tr>
<td></td>
<td>767th Step</td>
<td>$y = 309.63x^{-2.029}$</td>
<td>0.9349</td>
</tr>
<tr>
<td>Model 5</td>
<td>59th Step</td>
<td>$y = 180.1x^{-1.695}$</td>
<td>0.6736</td>
</tr>
<tr>
<td></td>
<td>767th Step</td>
<td>$y = 97.882x^{-1.617}$</td>
<td>0.8410</td>
</tr>
<tr>
<td>Model 6 ($\lambda = 0.5$)</td>
<td>59th Step</td>
<td>$y = 95.549x^{-1.7483}$</td>
<td>0.8384</td>
</tr>
<tr>
<td></td>
<td>767th Step</td>
<td>$y = 56.86x^{-1.6021}$</td>
<td>0.8580</td>
</tr>
<tr>
<td>Model 6 ($\lambda = 1.0$)</td>
<td>59th Step</td>
<td>$y = 29.842x^{-1.6339}$</td>
<td>0.9228</td>
</tr>
<tr>
<td></td>
<td>767th Step</td>
<td>$y = 120.68x^{-1.5628}$</td>
<td>0.6713</td>
</tr>
<tr>
<td>Model 6 ($\lambda = 1.5$)</td>
<td>59th Step</td>
<td>$y = 45.632x^{-1.7433}$</td>
<td>0.9646</td>
</tr>
<tr>
<td></td>
<td>767th Step</td>
<td>$y = 29.842x^{-1.6339}$</td>
<td>0.9228</td>
</tr>
</tbody>
</table>
Network Structures and Real People’s Network

- Judging from network indices…
  - The network meet small world phenomenon, scale freeness.
  - The network have a high clustering coefficient

- It could be concluded that Model 4 and Model 6 (Lambda = 0.5) fit reality.
  - The averages of shortest path are low.
  - Clustering coefficients are relatively high.
  - Degree distributions have good fit with power law.

- We will select Model 4 and Model 6 (Lambda = 0.5).
  - Examine the time series of the balance that deducts expenditure (pension benefit) from revenue (payment of premium).
  - Examine each agent role in network using betweenness centrality.
We can see that agent’s distrust in public pension system and its propagation have a decisive influence on public pension system.

- If distrust is not propagated, the year when pension premium fund go negative is about 2060.
- If, on the contrary, distrust is propagated, the year when pension premium fund go negative is about 2050.
- In this case, the amount of money (tax or the other forms) that government (people) should compensate for the shortfall should be unduly generous.
Each Agent Role and Pension Premium Fund

- Exploring each agent role in network using betweenness centrality and the number of links that they have.

- Many agents whom the value of betweenness centrality is high have negative attitude score.
- In respect of Model 6, they are also hub-agents.
- It is reasonable to suppose that these situations had a profound influence on pension premium fund in later steps.
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Conclusion and Future Works

✓ **Conclusion**

- People’s distrust in public pension system and the propagation of distrust has a decisive influence on the pension premium fund.
- Not hub-agents but agents whom the value of betweenness centrality is high have significant role to the future pension premium fund.
- The sharp decline in pension premium fund by the propagation of people’s distrust in public pension system is real possibility.
  - Because we select some network models, which fit well in real people’s network, judging by the various network indices.

✓ **Future Works**

- A continuous examination of the mechanism of people’s network, e.g. the introduction of the other network indices.
- Using our network models, we will verify a positive policy impacts that comes from decreasing people’s distrust in public pension system.