# Direct and Indirect Effects of New High Speed Rail Service:

## An Empirical analysis Using Japanese Mobile Phone Location Data

20th October., 2017

IVT – Seminar | Big data: Results from Japan

**Hiromichi Yamaguchi** (Kanazawa University),

Wataru Nakanishi, Daisuke Fukuda (Tokyo Tech.),

Kay W. Axhausen (ETH zurich)


金沢大学
KANAZAWA UNIVERSITY

# Hokuriku High Speed Rail (HSR)


**New Hokuriku HSR**

- Operation start date: 14th Mar. 2015
- Tokyo ⇔ Kanazawa (450 km)
  3h. 50 min. → 2h. 30min. **(- 80 min. !)**

# Observing the effects of new Hokuriku HSR

– New HSR reduce the travel time greatly.

→ expected to significantly change the travel patterns.

Ex. realizing of latent demand,
changing travel destination, …

– **Mobile phone location data**

✓ Whole nation-wide population distribution

✓ Data at arbitrary points in time

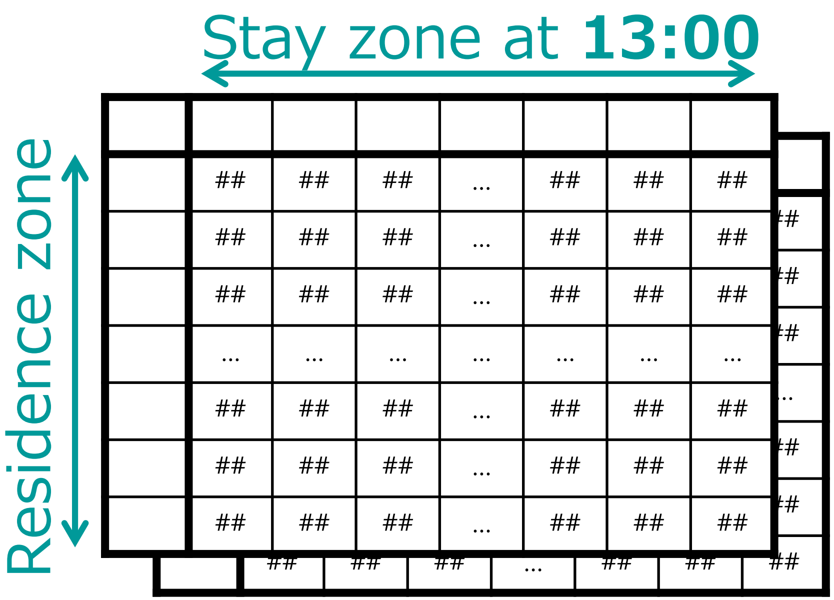
→ enable us to analyze
the accurate change of nation-wide travel patterns.

**Question:** How did Hokuriku HSR change
the Japanese long-distance travel pattern?

# Data: Mobile Space Statistics by NTT-Docomo

Residence – Stay zone estimated population **(stock)** matrices

- 50 × 50 zone (prefectural size)
- estimated the data of 70 million mobile phones
- **Average value for one year**
  (before and after the HSR operation start)




» "Before"
(2014.3.1-2015.2.28)

» "After"
(2015.4.1-2016.3.31)

# Basic aggregation of MSS data (1)

| | (1) Before<br>14.3.1 ~ 15.2.28 | (2) After<br>15.4.1 ~ 16.3.31 | (2) - (1)<br>((2) / (1)) |
|---|---|---|---|
| **Tokyo →Kanazawa** | 3,311 | 5,200 | +1,890<br>(×1.57) |
| **Kanazawa →Tokyo** | 3,452 | 3,903 | +450<br>(×1.13) |

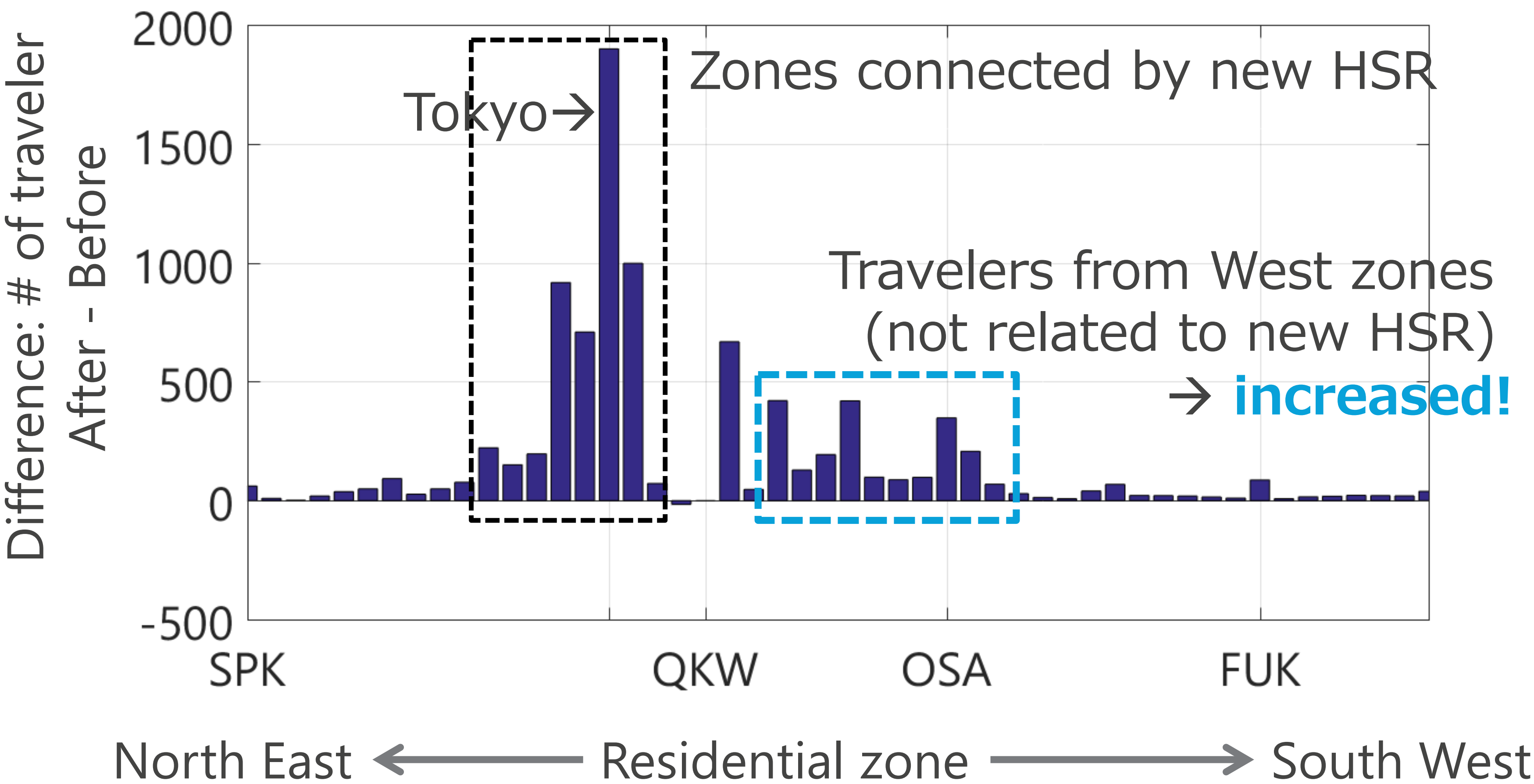
**Asymmetric Increase**

Effects on Tokyo Residents

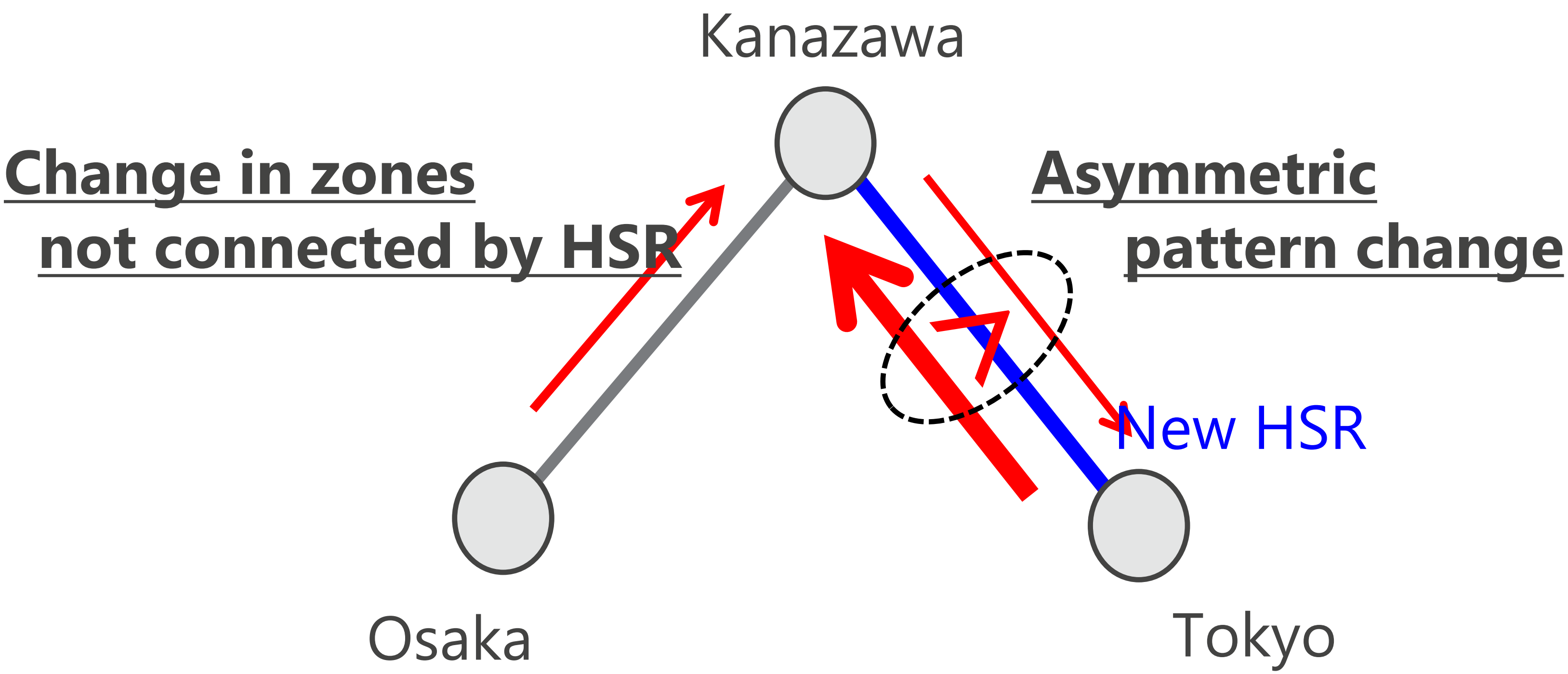
≫ Effects on Kanazawa Residents

# Basic aggregation of MSS data (2)

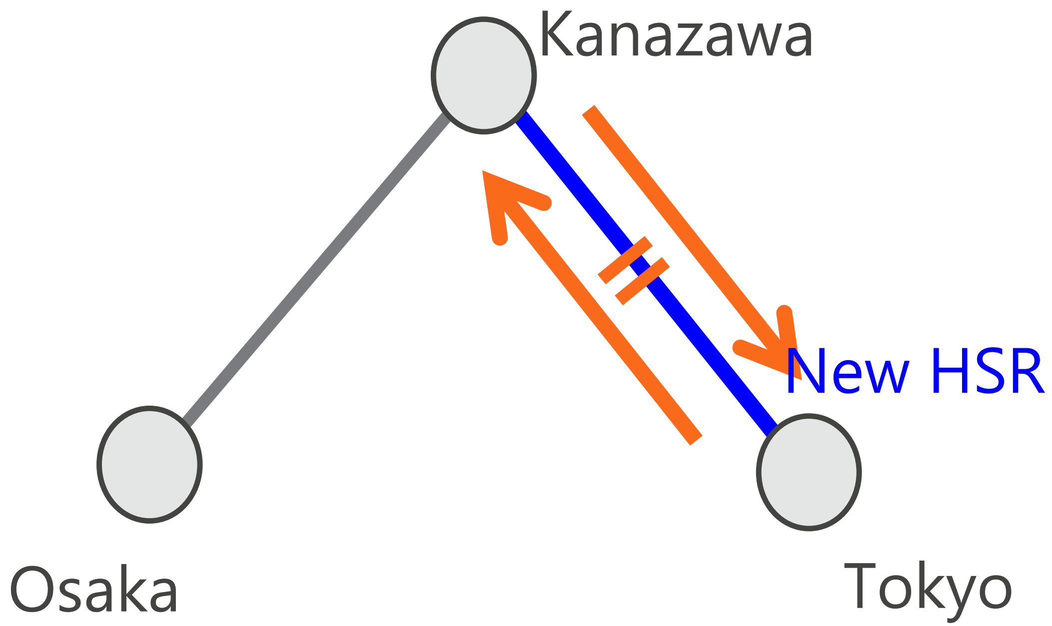
**Change in # of traveler to Kanazawa (QKW) :**



# Summary of basic aggregation:



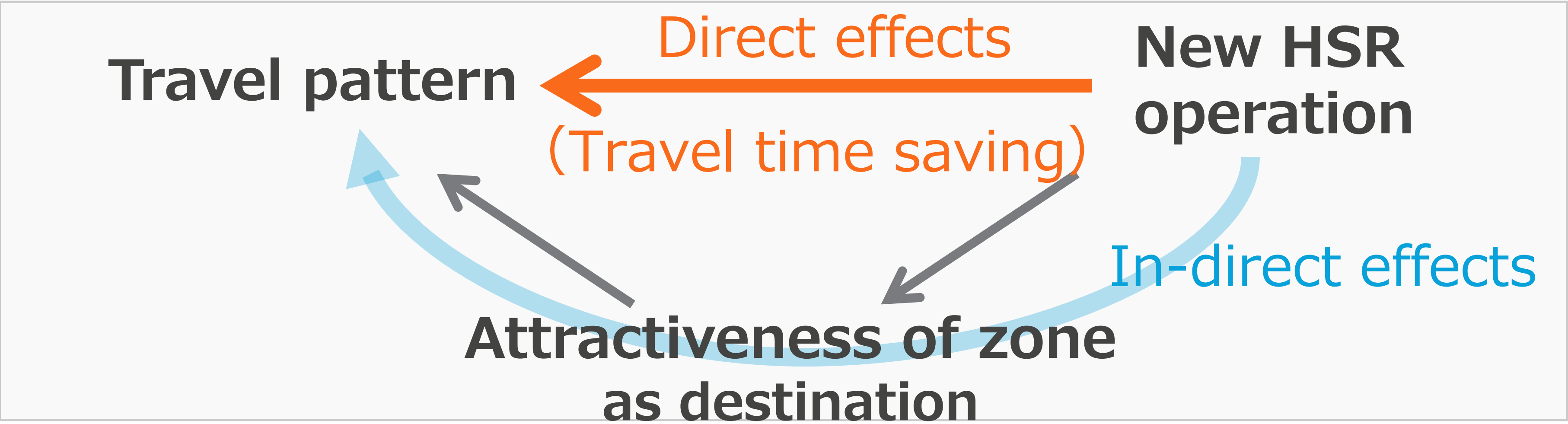
# Expected effects of travel time savings




– Symmetric (travel time are similar among directions)
– Limited in the HSR users

→ Impossible to explain the observed patterns.

# Direct and In-direct effects of new HSR



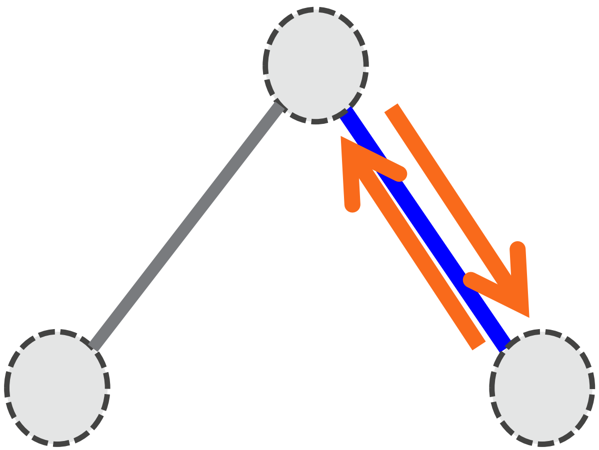

- New HSR operation may have affected on the attractiveness of zones.

  ex. changing the socio-economical condition,
  advertisement effect, and so on...

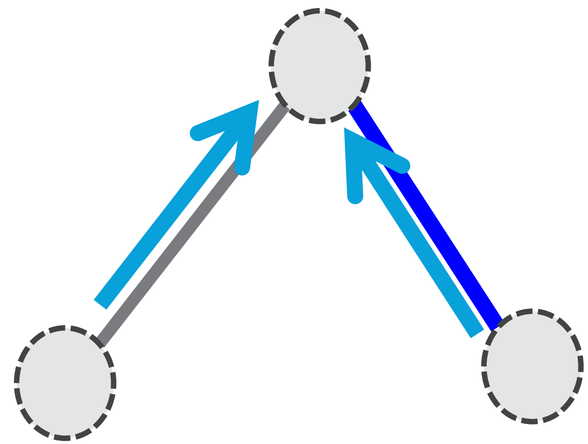
- In this pattern (indirect pattern), the spatial pattern of HSR effects are different.

# Spatial patterns of direct and in-direct effect

**Direct effect**



**In-direct effect**



- In-direct effect are similar among all residence zones
- It looks possible to reproduce
  observed patterns by combining these two effects.

**Question:** How much was the quantity of these effects?

**Key Idea:** “spatial-pattern decomposition of MSS data”

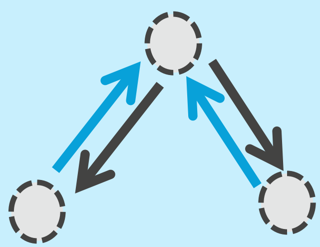
# Spatial-pattern decomposition of observation matrix

**Observed matrix by MSS** Residuals

$$\boldsymbol{B}_{\mathrm{aft}} - \boldsymbol{B}_{\mathrm{bef}} = \boldsymbol{V} + \boldsymbol{C} + \boldsymbol{E}$$

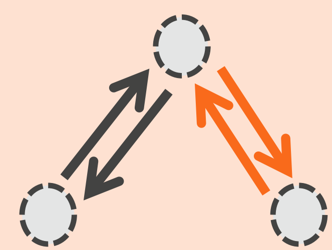
**In-direct effect matrix**
(similar value in each column)

| | | | | |
|---|---|---|---|---|
| | 0 | ## | ## | ## |
| | ## | 0 | ## | ## |
| | ## | ## | 0 | ## |
| | ## | ## | ## | 0 |



**Direct effect matrix**
(symmetric matrix)

| | | | | |
|---|---|---|---|---|
| | 0 | ## | ## | ## |
| | ## | 0 | ## | ## |
| | ## | ## | 0 | ## |
| | ## | ## | ## | 0 |



# Target value:
# "Log-ratio with diagonal component"

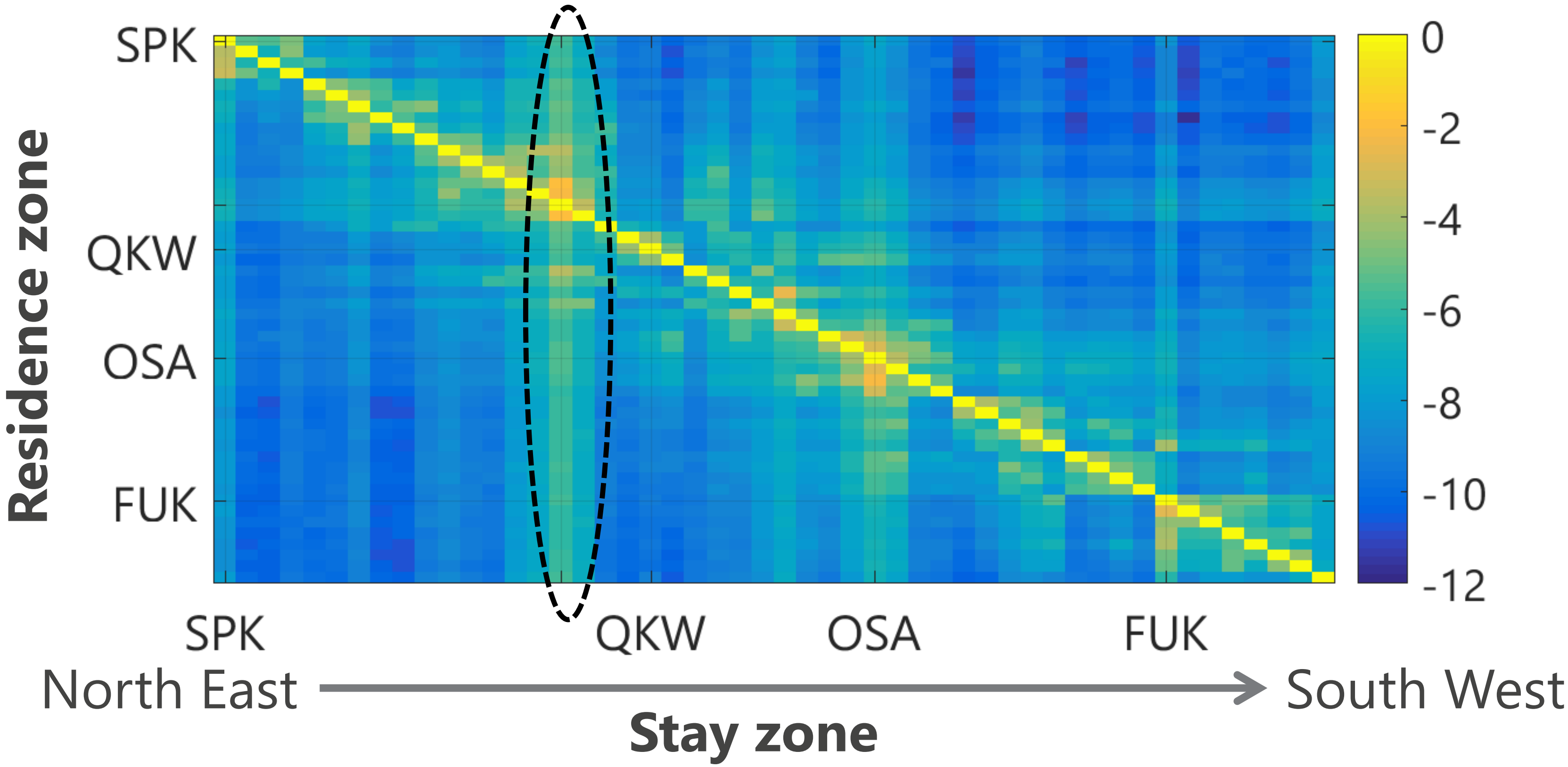
$$b_{ij,t} = \ln\left(\frac{N_{ij,t}}{N_{ii,t}}\right)$$

→ Eliminate population size difference

◆This means the **fixed term of Utility** of destination choice logit model

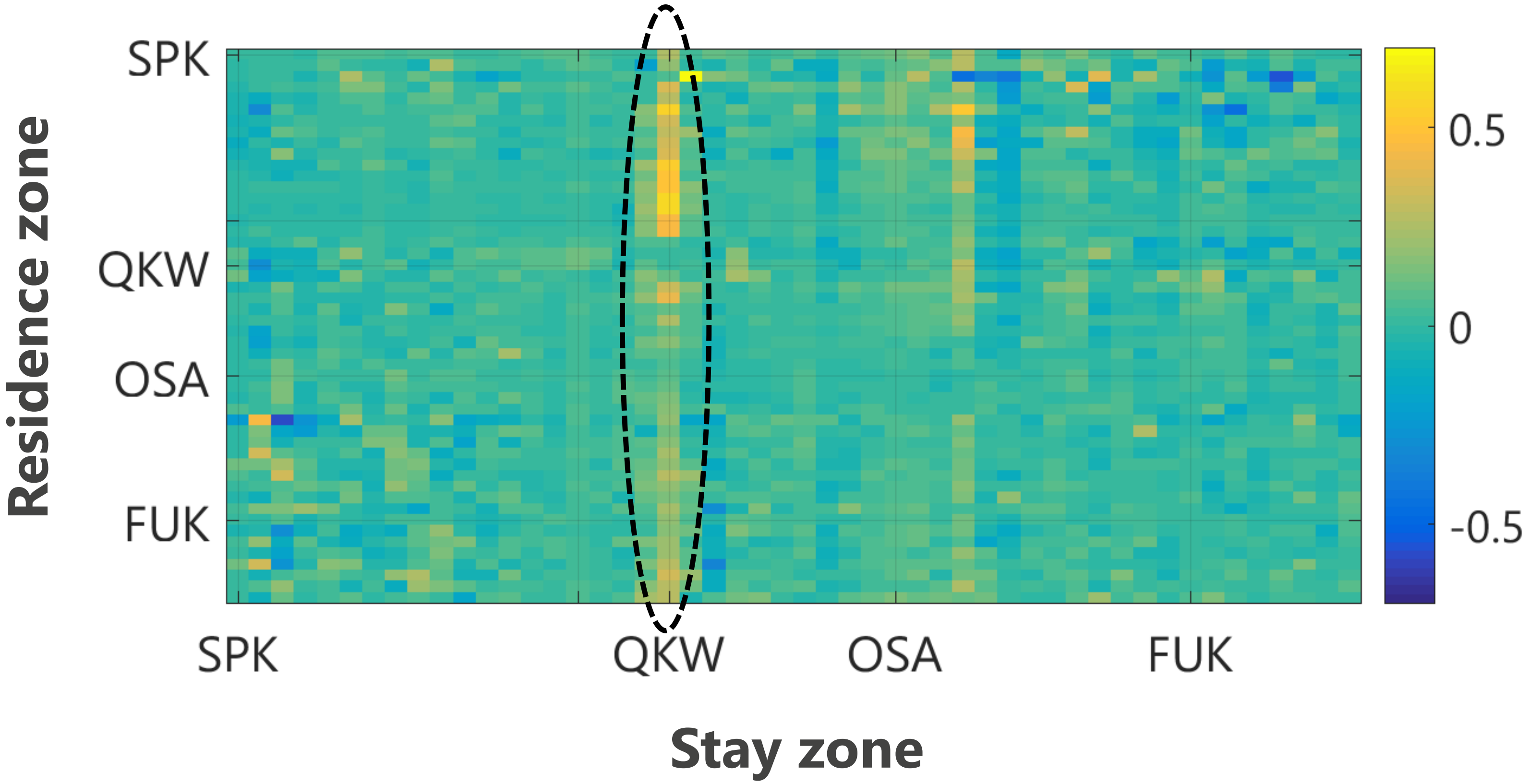
$$b_{ij,t} = \ln\left(\frac{N_{ij,t}}{N_{ii,t}}\right) = \ln\left(\frac{p(j|i,t)}{p(i|i,t)}\right) = \ln\left(\frac{\exp V_{ij,t}}{\exp V_{ii,t}}\right) = V_{ij,t} - V_{ii,t}$$

# Log-ratio matrix（$\boldsymbol{B}_{\mathrm{bef}}$）




– Diagonal components equal to zero
– Values of Tokyo (as stay zone) are large for all residence zone

# Difference of Log-ratio matrix ($\boldsymbol{B}_{\mathrm{aft}} - \boldsymbol{B}_{\mathrm{bef}}$)




– Values of Kanazawa (as stay zone) are increased for most residence zone

# Estimation methodology (1)

$$\min_{(\boldsymbol{V},\boldsymbol{C})} \|\boldsymbol{E}\|_2 = \sum_{(i,j)} \left\{ \left( b_{ij,\mathrm{aft}} - b_{ij,\mathrm{bef}} \right) - \left( v_{i,j} - c_{i,j} \right) \right\}^2$$

s.t.

$$v_{i,j} = v_{i,k} \qquad \forall \{(i,j,k) | i \neq j, i \neq k, (i,j,k) \in (Z \times Z \times Z)\}$$

$$c_{i,j} = c_{j,k} \qquad \forall \{(i,j) | i \neq j, (i,j) \in (Z \times Z)\}$$

$$v_{i,i} = c_{i,i} = 0 \qquad \forall i \in Z$$

– Here, $(\boldsymbol{V}', \boldsymbol{C}')$ satisfies $(\boldsymbol{V} + \boldsymbol{C}) = (\boldsymbol{V}' + \boldsymbol{C}')\ \forall k \in R$

- $\boldsymbol{V}' = \boldsymbol{V} + k\boldsymbol{A}$
- $\boldsymbol{C}' = \boldsymbol{C} - k\boldsymbol{A}$

→ We cannot estimate unique $(\boldsymbol{V}, \boldsymbol{C})$ !

$\boldsymbol{A}$

| | | | | |
|---|---|---|---|---|
| | 0 | 1 | 1 | 1 |
| | 1 | 0 | 1 | 1 |
| | 1 | 1 | 0 | 1 |
| | 1 | 1 | 1 | 0 |

# Estimation methodology (2) (≒ **LASSO**)

[Step-1]

$$\min_{(\boldsymbol{V}',\boldsymbol{C}')} \|(\boldsymbol{B}_{\mathrm{aft}} - \boldsymbol{B}_{\mathrm{bef}}) - (\boldsymbol{V}' + \boldsymbol{C}')\|_2$$

s.t.

$$v'_{i,j} = v'_{i,k} \quad \forall \{(i,j,k) | i \neq j, i \neq k, (i,j,k) \in (Z \times Z \times Z)\}$$

$$c'_{i,j} = c'_{j,k} \quad \forall \{(i,j) | i \neq j, (i,j) \in (Z \times Z)\}$$

$$v'_{i,i} = c'_{i,i} = 0 \quad \forall i \in Z$$

$v'_{1,2} = 0$ ← fix one parameter

[Step-2]

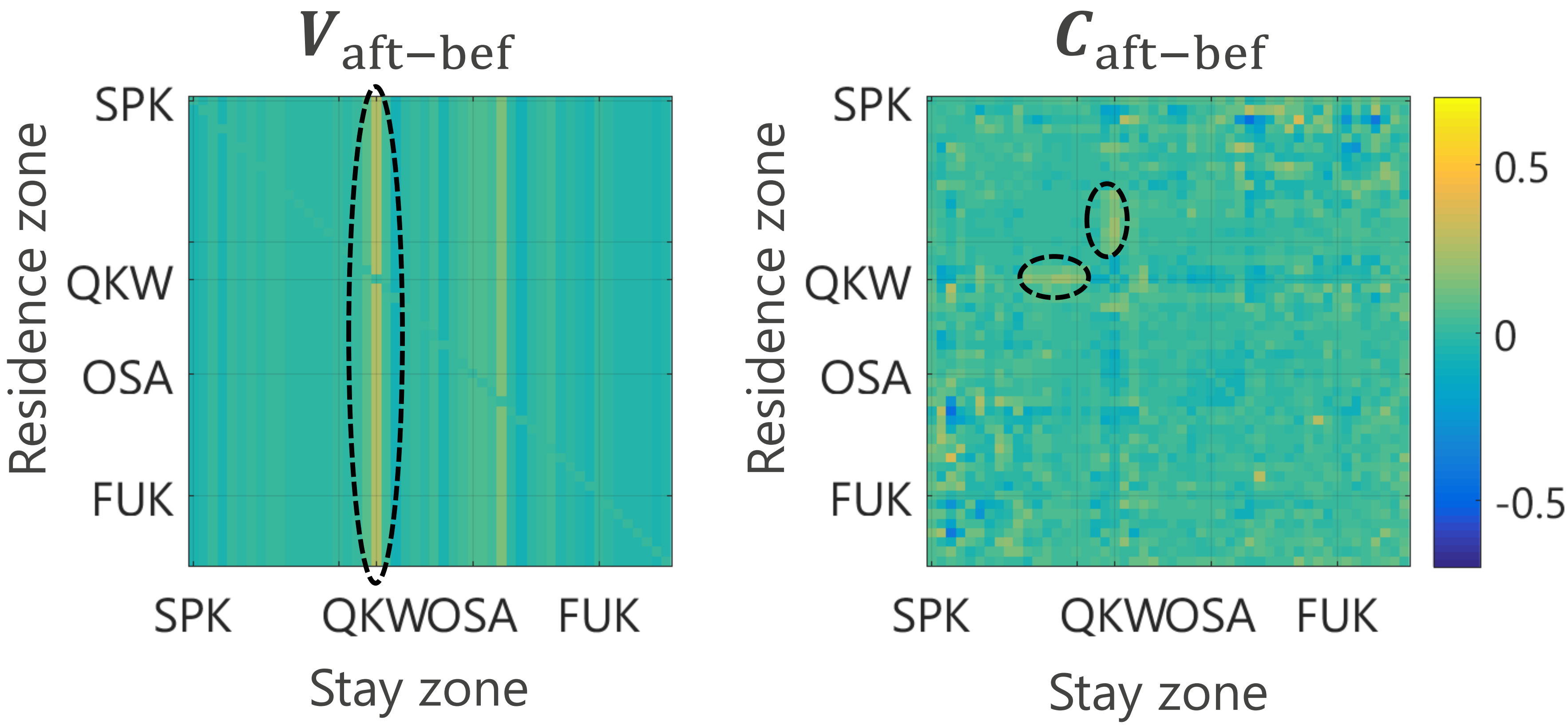
$$\min_{k} \|\boldsymbol{C}\|_1 = \sum_{(i,j)\in(Z\times Z)} |c_{i,j}|$$

s.t. $\boldsymbol{C} = \boldsymbol{C}' - k\boldsymbol{A}, \boldsymbol{V} = \boldsymbol{V}' + k\boldsymbol{A}$

decide $k$ as minimizing **"L1 norm"** of matrix $\boldsymbol{C}$

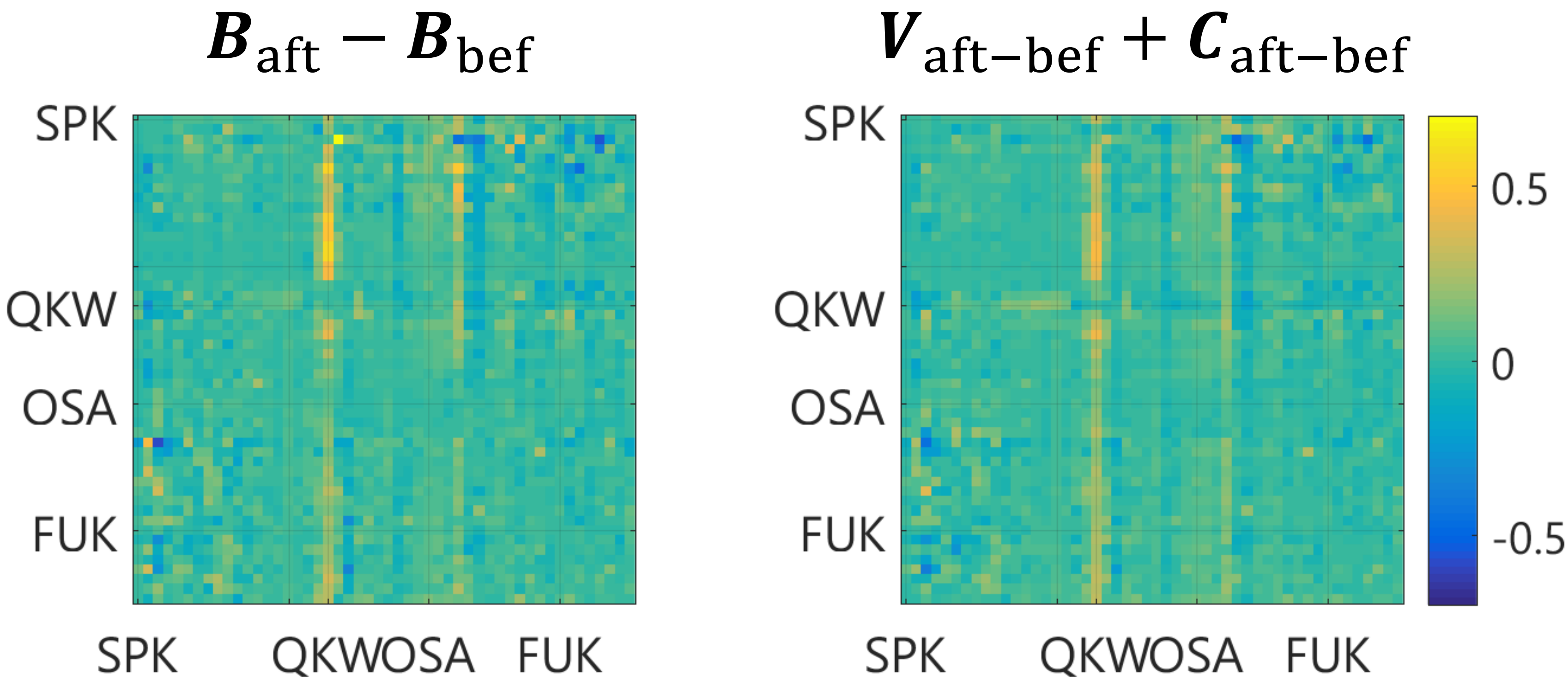
Assumption: matrix $\boldsymbol{C}$ is sparse.
(most components of $\boldsymbol{C}$ are close to zero.)

# Estimated results of two matrices




- **Direct effects**
  between Tokyo metropolitan zones ⇔ Kanazawa.
- **In-direct effects** on Kanazawa.

# Reproducibility of difference matrix




Observed matrix ($B_{\text{aft}} - B_{\text{bef}}$)

$\fallingdotseq$ Estimated matrix ($V_{\text{aft-bef}} + C_{\text{aft-bef}}$)

→ Most changes in matrix $B$ are explained by two patterns!

# Direct effects vs. In-direct effects (calculation)

◆Calculate the effects on # of traveler
by logit model formulation
→ compare between direct and in-direct effects

**# of traveler increase by both effects**

$$X_{ij,\mathrm{both}} = \mathrm{POP}_i \left\{ \frac{\exp\left(b_{ij,\mathrm{bef}} + v_{ij} + c_{ij}\right)}{\sum_{j \in Z} \exp\left(b_{ij,\mathrm{bef}} + v_{ij} + c_{ij}\right)} \right\} - N_{ij,\mathrm{bef}}$$

**# of traveler increase by only direct effects**

$$X_{ij,\mathrm{direct}} = \mathrm{POP}_i \left\{ \frac{\exp\left(b_{ij,\mathrm{bef}} + c_{ij}\right)}{\sum_{j \in Z} \exp\left(b_{ij,\mathrm{bef}} + c_{ij}\right)} \right\} - N_{ij,\mathrm{bef}}$$

# Direct effects vs. In-direct effects (results)

| | (1) $X_{ij,\mathrm{direct}}$ | (2) $X_{ij,\mathrm{both}}$ | (1) / (2) |
|---|---|---|---|
| Tokyo →Kanazawa | +551 | +1,617 | 0.34 |
| Kanazawa → Tokyo | +583 | +647 | 0.90 |

- 66% of increase in Tokyo → Kanazawa was in-direct effects.
  ～ In HSR effects, in-direct patterns are strong.
- In-direct effects in Kanazawa → Tokyo was small.
  ～ This is the cause of asymmetric change.

# Summary

- Estimating the HSR effects on OD matrix
  into direct and in-direct effects
  - By mobile phone location data.
  - Decomposition by LASSO approach.

- Direct and in-direct effects on Hokuriku HSR
  - There were large in-direct effects on Kanazawa zone
    → This caused the asymmetric pattern.
  - In-direct effects on inflow to Kazanawa zone
    were larger than direct effects.
    → In-direct effects are major effects of new HSR?

# Discussion

- What does the **in-direct effect** mean?
  - change of socio-economical condition?
  - announcement / advertisement?

  → we can identity by the time-series decomposition of more longer period.

- Can existing travel demand forecasting models deal with this strong in-direct effects?

# Thank you for your kind attention

Hiromichi Yamaguchi
hyamaguchi@se.kanazawa-u.ac.jp