Effects of COVID-19 vaccine

on transportation choice probability and discretionary activities

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1. Background

- COVID-19 epidemic in Japan has restricted the behavior of many people.
- Government recommended vaccination to turn around the Japanese economy by going out.
- However, the supply of vaccine was not keeping up with those who did not have a large hospital nearby or who could not make an appointment.
- If vaccination has any effect on people's behavior, then the government should give more importance to this issue.

ワクチン接種が人々の行動に与える影響は？

What was the impact of vaccination on people's behavior?

Mandatory

- 人口密度
- 交通手段選択

- Population density
- Mode choice

×

Vaccination

×

Discretionary

- 外出確率

- Probability of going out

2. Basic Analysis

- Fig.1 shows the number of new COVID-19 patients.
- In order to consider people's outings during the pandemic, the analysis covered end of the emergency declaration period
- 図1はCOVID-19の新規感染者数の推移を示す。
- パンデミック下における人々の外出を検討するため、緊急事態宣言終期（2021年7月~11月）を対象とした。

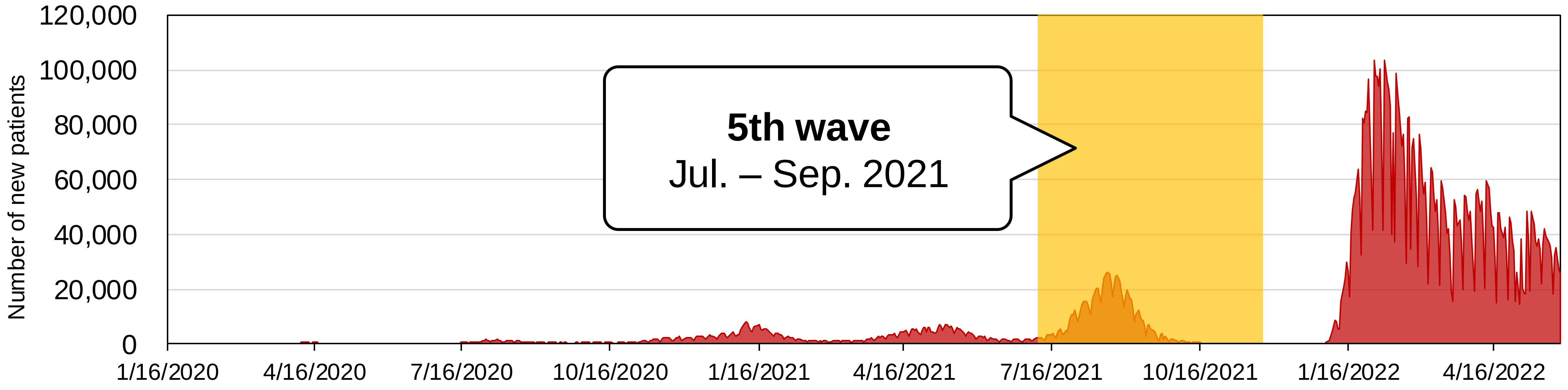


Fig.1. The number of new patients

3. Mandatory

- COVID-19 pandemic affects traffic behavior[1)].
- Focused on whether there are spatial differences due to differences in population density, rather than time-series changes

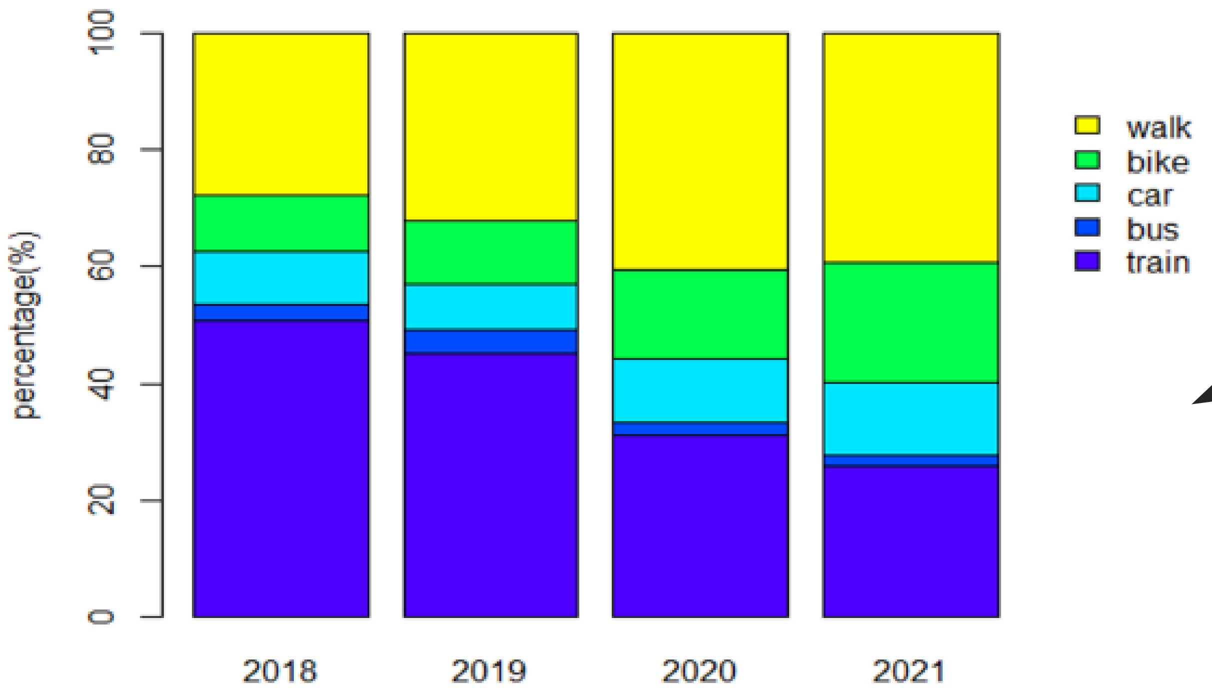
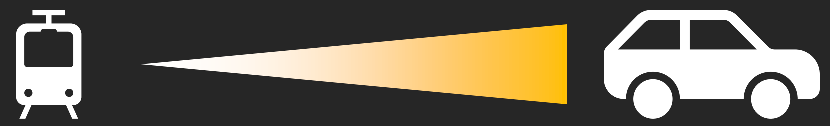


Fig.2. Percentage change in representative transportation by age group[1)]

Public Transportation → **decrease**
The others → **increase**

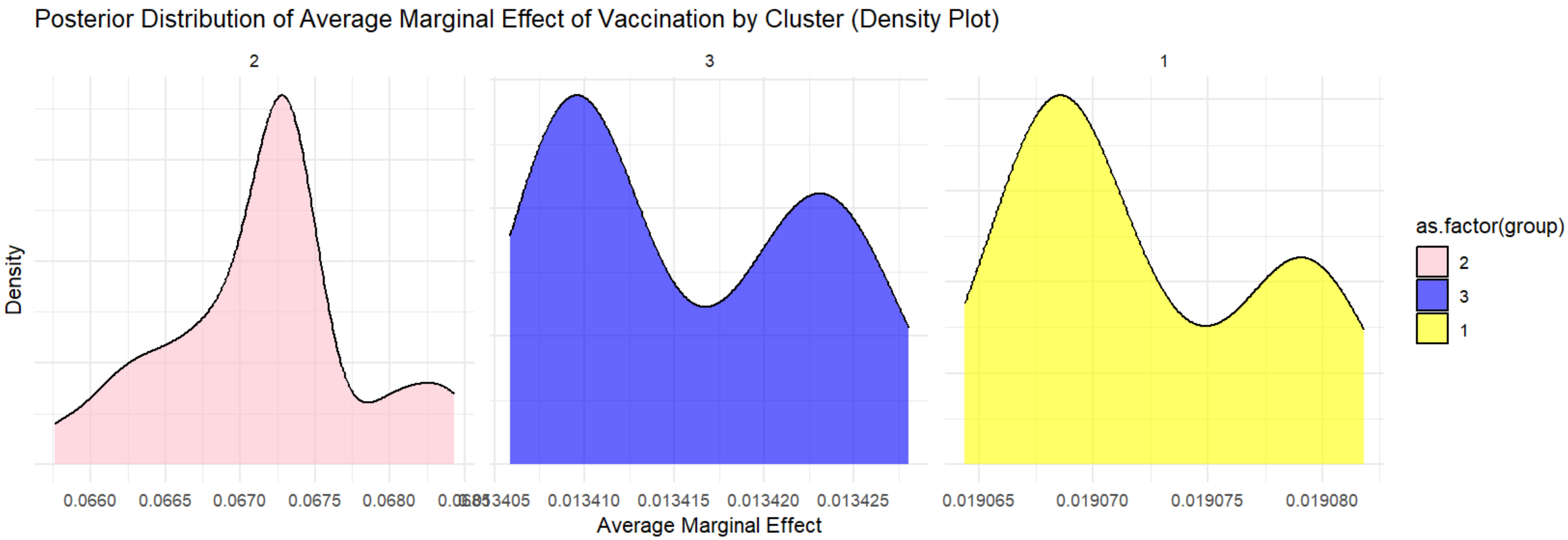


1) Joint A Team(2023) “A travel mode choice model considering self-selection of vaccination”

Made an interesting discovery!!

The Largest Population Group(Group 2 Pink) Exhibits a Distinct Distribution of Effects!!

The other two groups share the same bimodal distribution



Smaller population group

- **Spatial Heterogeneity**
  - ✓ Considered by Hierarchical Bayes.
  - ✓ As shown in the figure on the right, the population is divided into three cluster based on its population
- **Spatial Correlation**
  - ✓ Considered by Spatial adjacency matrix.
  - ✓ The spatial adjacency matrix assigns weights based on Distance between Observations: the closer the distance, the heavier the weight

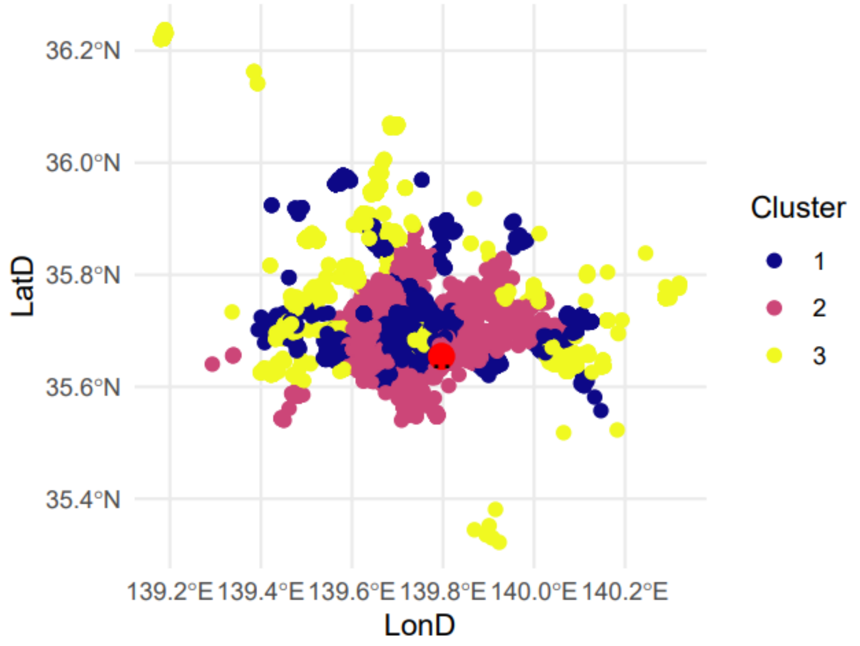
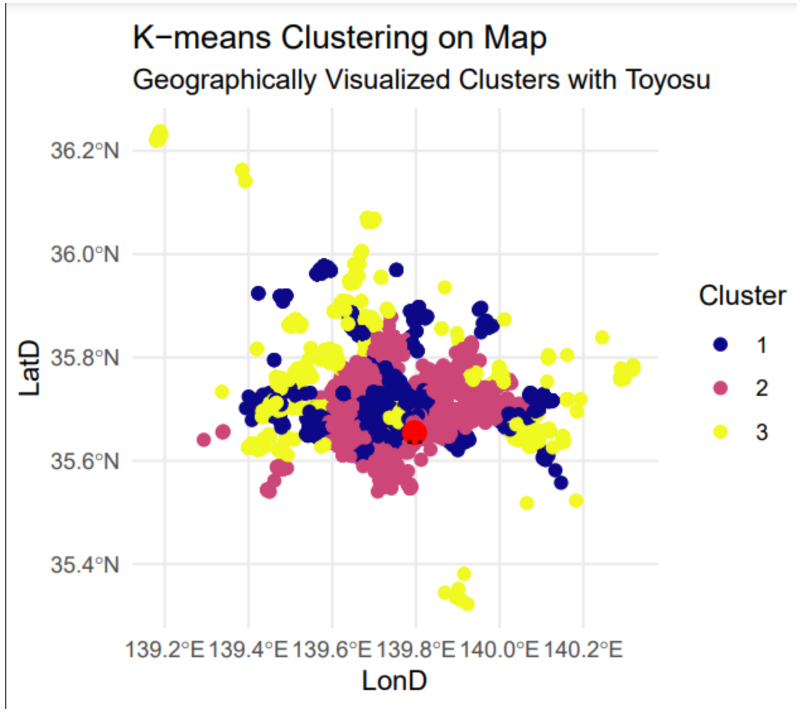


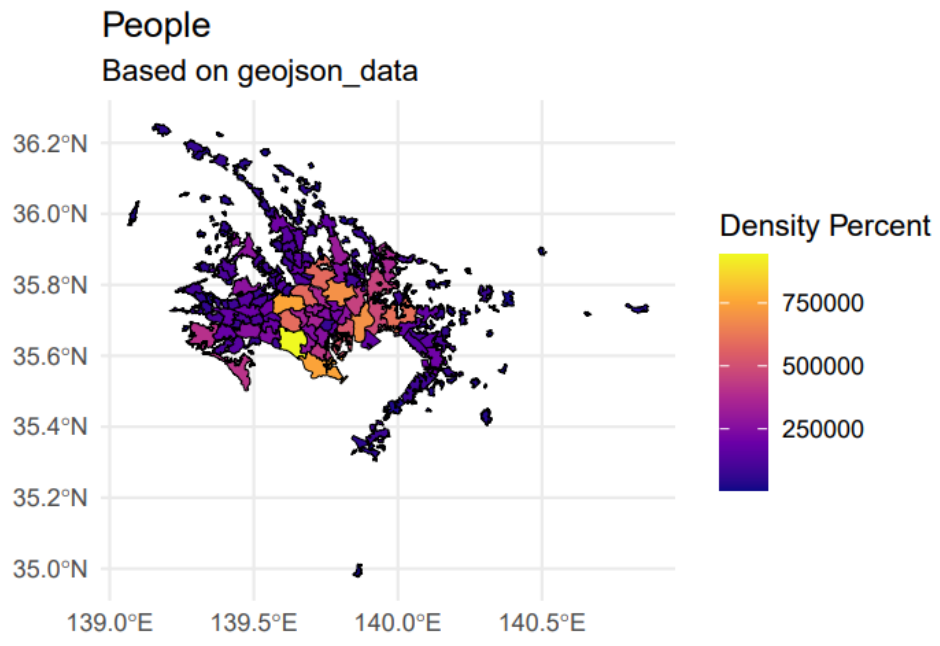
Fig.3. K-means Clustering on Map

- **Basic Data**
  - ✓ Trip Data
  - ✓ GIS data
  - ✓ Individual Characteristics data
  - ✓ Population data(国土数値情報)
- **Selected Sample**
  - ✓ Trip Purpose : Business and Commuting to work or school
  - ✓ Time : Before 10 a.m. in the morning
  - ✓ Area : Tokyo + Chiba + Kanagawa + Saitama + Ibarak

Spatial Heterogeneity

Blue: 2nd largest population area
Pink: The largest population area
Yellow: The least populous area
Red point: Toyosu





- **Empirical Model**

✓ Random Utility Model

Spatial Unit i and individual n ‘s indirect utility

$$v_{ni} = X_{F_n}\boldsymbol{\alpha} + X_{R_n}\boldsymbol{\beta_i} + \rho \sum_{j \neq i} w_{ij} v_{nj} + \epsilon_{ni}$$

Weighted Utility

$$v_{ni} = A^{-1}(X_{F_n}\alpha + X_{R_n}\beta_i + \epsilon_n)$$
$$A = I - \rho W$$

$i \in \{1,2,3\}: Spatial\ Unit\ determined\ by\ Population$

$n \in \{1, \ldots 300\}$

$\beta_i: Random\ Coefficient\ with\ Variance\ determined\ by\ Spatial\ group$

$Trans$: Public Transportation or Not Public Transportation

$Fare$:

$Vaccine$:

$Price_v$: Vaccine Price

Assumptions

✓ Identification Assumption

Conditional Independence

$$E[Vaccine|Age, Income] = 0$$

Interpretation

The status of vaccination (whether vaccinated or not) becomes conditionally independent on average given age and income

Estimation Model

✓ Weighted Indirect Utility

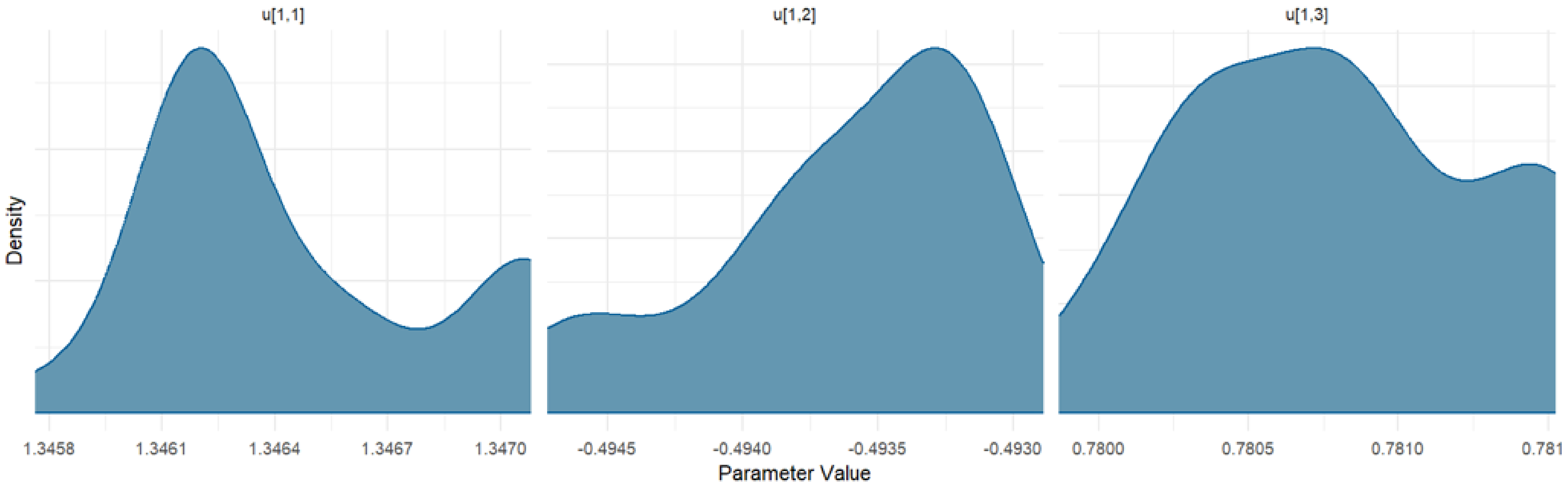
$$v_{ni} = A^{-1}(X_{Fix}\beta + X_{Rnd}(Z + u_i) + \epsilon_n)$$
$$A = I - \rho W$$

✓ Public Transportation Choice Probability

$$P(y_{ni} = 1) = \frac{\exp(v_{ni})}{1 + \exp(v_{ni})}$$

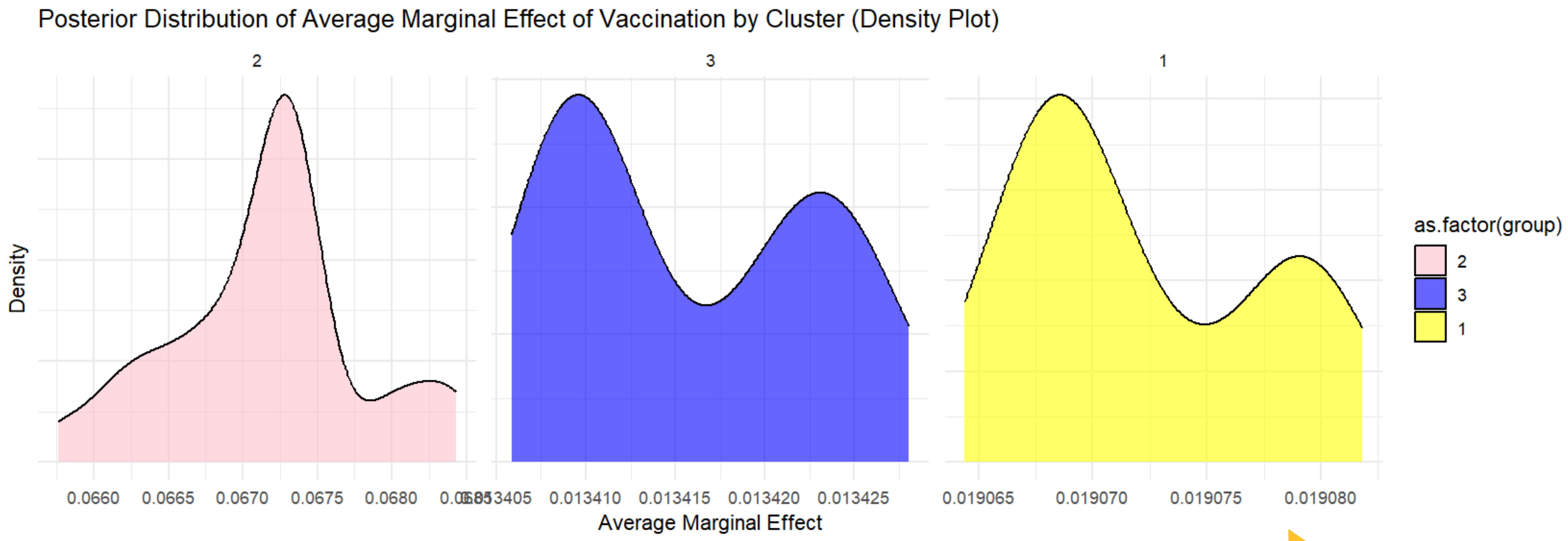
Outcome

	Mean	Standard Error
Vaccination_Fix	0.451	0.000301
Vaccination_Random (Group1)	1.346	0.000395
Vaccination_Random (Group2)	-0.494	0.000507
Vaccination_Random (Group3)	0.781	0.000505



- **AME**

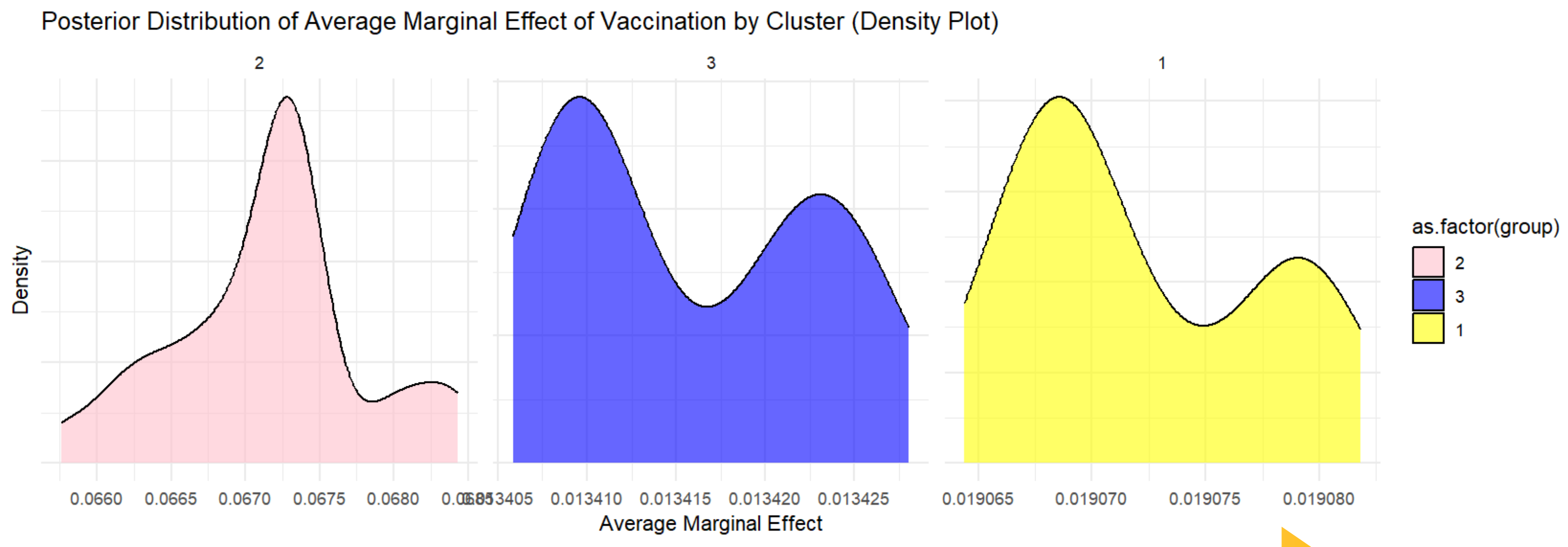
	Mean	Lower CI(95%)	Higher CI(95%)
AME(Group1)	0.019	0.019	0.019
AME(Group2)	0.067	0.066	0.068
AME(Group3)	0.013	0.134	0.013



Smaller population group

The Largest Population Group Exhibits a Distinct Distribution of Effects!!

There is a clear difference in the value of the average marginal effect and the shape of the distribution between the largest population group and the other groups. The group with the largest population has a unimodal distribution, while the other groups exhibit a bimodal distribution. In areas with larger populations, the effect of vaccination is clearly positive and significant.
In Group 2, which has the largest population, the probability of choosing private public transportation increases by 6% due to vaccination. In the second and third largest population groups, the probability increases by only 1.6% to 1.9% due to vaccination



Smaller population group

Counterfactual

By prioritizing vaccine distribution in highly populated areas, it is possible to encourage the preferential use of public transportation

There is about **5% lower public transportation probability in effect compared to the group with the largest population**, so prioritizing vaccine distribution could increase public transportation usage by an average of 5%

Choosing public transportation **saves energy** and allows people to **use their income more freely**, thereby **improving welfare**

Bimodality reflects two patterns of behavior: those who choose public transportation and those who do not. In contrast, the group with the largest population shows a **single pattern** of people choosing public transportation

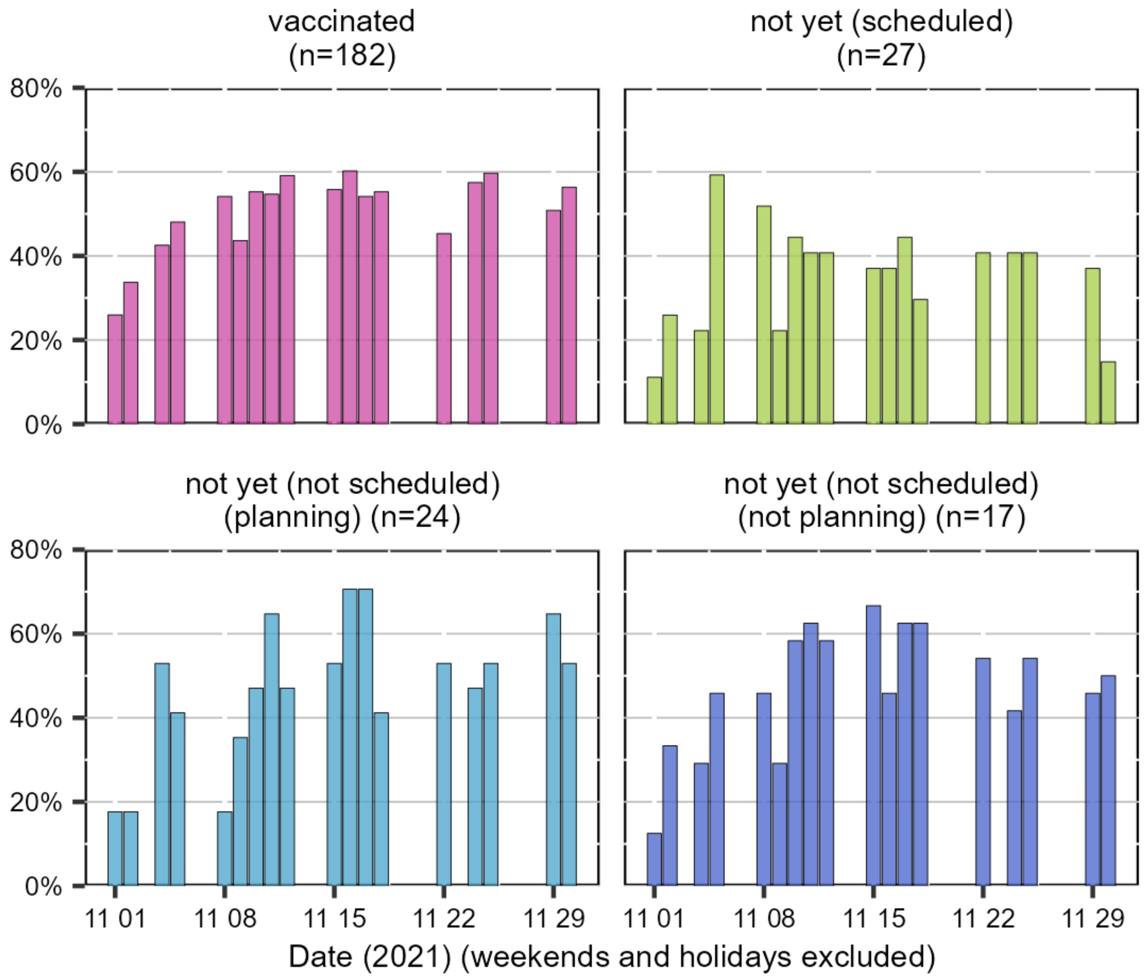
4. Discretionary

- Whether going out or not for discretionary activities might be affected by the individual's risk perception of the infection.
- Since risk perception cannot be observed, we used "vaccination status" as a proxy variable.
- Individual attributes and environmental conditions that may affect the probability of going out were also included in the model.
- **Data**：Tokyo Nov.2021

Estimation

$$\log\left(\frac{pi}{1-pi}\right) \sim a + \sum (b_k * D_k) + e$$

note : Vaccination itself was not affected much by individual attributes



Percentage of those who went out for discretionary activities within the day by vaccination status

- Compared to those who had already got vaccinated, those who were waiting had 31% (15%~44%) slighter probability of going out for discretionary activities on weekdays, presumably due to fear of infection.
- Those who had no schedule for vaccination were going out for discretionary activities as much as those who got vaccinated; those who even did not have intention of vaccination were more likely to go out (but not statistically significant)

Perceived risk

vaccinated (reference) | not yet (scheduled) | not yet (not scheduled) (planning) | not yet (not scheduled) (not planning)

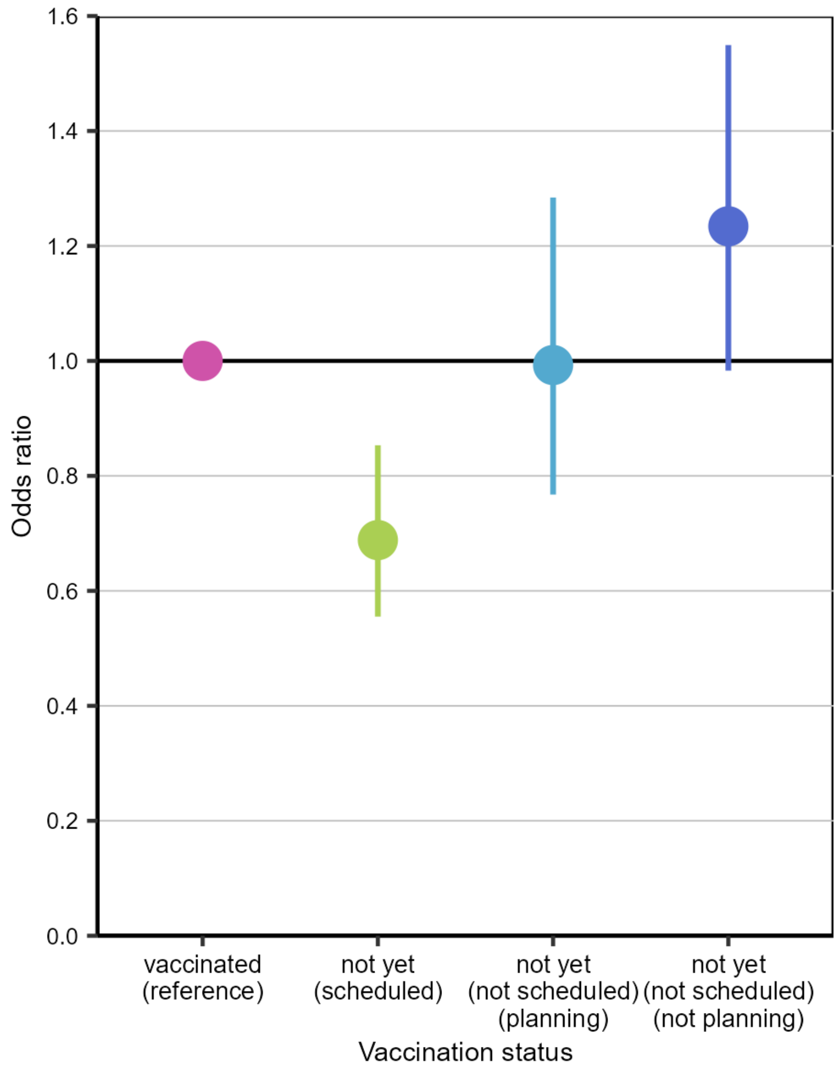


Fig.5. Odds ratio of the probability of going out for discretionary activities by vaccination status

4. Discretionary

- Other variables with great magnitude were:
  - ✓ "homemaker" (+161% to office workers, due to grocery shopping?)
  - ✓ "living with children" (+45% to no-child, due to the need for *decent* lifestyle?)
  - ✓ "owning a car" (-41% to non-owner, due to bulk purchase?)

Table.1. Estimation results

Variable name (reference category)	Odds ratio	lower 95% ci	upper 95 ci	*p* value	
Vaccination status (ref: vaccinated)					
not yet (scheduled)	0.69	0.56	0.85	0.00	**
not yet (not scheduled, planning)	0.99	0.77	1.28	0.96	
not yet (not scheduled, not planning)	1.23	0.98	1.55	0.07	.
Age (ref: ~20s)					
30s	1.92	1.37	2.69	0.00	**
40s	1.63	1.17	2.28	0.00	**
50s	2.00	1.42	2.81	0.00	**
60s~	2.60	1.80	3.76	0.00	**
Job (ref: Office worker)					
self-employed	1.24	0.95	1.63	0.12	
part-timer	1.10	0.84	1.46	0.48	
homemaker	2.61	1.75	3.88	0.00	**
unemployed	2.14	1.35	3.39	0.00	**
< 2 million yen	0.36	0.22	0.59	0.00	**
< 6 million yen	1.07	0.89	1.28	0.48	
Household income (ref: < 10million yen)					
< 15 million yen	1.13	0.95	1.34	0.18	
>= 15 million yen	1.03	0.82	1.29	0.81	
Living with (a) child(ren) (ref: no)					
yes	1.45	1.25	1.67	0.00	**
Owning (a) car(s) (ref: no)					
yes	0.59	0.50	0.69	0.00	**
Prefecture of residence (ref: Tokyo)					
Saitama	0.93	0.70	1.24	0.62	
Chiba	0.73	0.59	0.90	0.00	**
Kanagawa	1.41	1.11	1.79	0.01	**
Housing (ref: independent housing)					
mass housing	1.26	1.04	1.53	0.02	*
Weather (ref: sunny)					
sunny / cloudy	0.68	0.59	0.78	0.00	**
cloudy	0.97	0.78	1.19	0.75	
rainy	0.62	0.51	0.77	0.00	**
Number of observations	4,482				
AIC	5948.0				
LL(0)	-3104.7				
LL(β)	-2949.0				
-2[LL(0)-LL(β)]	311.4				

Notes: . $p<0.1$, * $p<0.05$, ** $p<0.01$. ci: confidence interval.


Thanks for your attention!!