Estimation of Residential Location Choice After the Great East Japan Earthquake Using a Latent Class Model Incorporating Psychological Factors

Team Tsukuba-F

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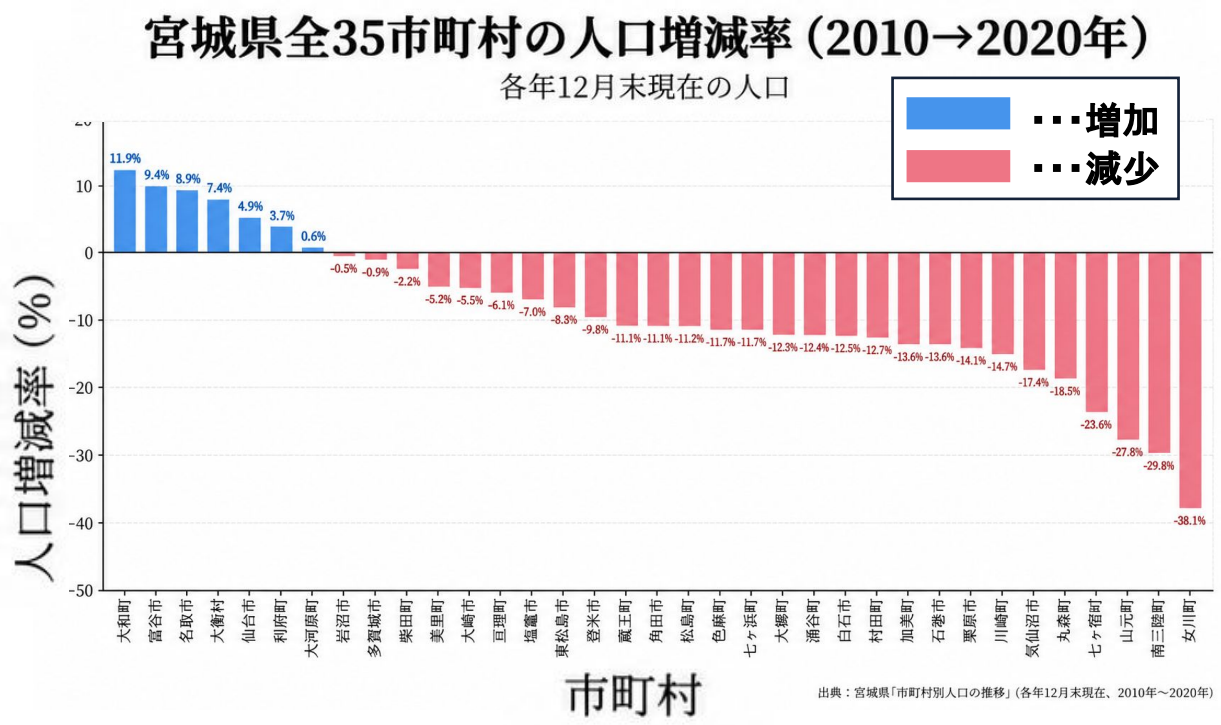
Background/purpose

Background

- Areas experiencing population decline following the Great East Japan Earthquake

▸ People migrating from suburbs to city centers

▸ Deterioration of local finances and public transportation access



Purpose

▸ **Identify the factors behind residential migration trends and determine the measures necessary for municipalities experiencing population decline to curb that decline.**

Hypothesis

▸ The choice of residential location following a disaster is influenced not only by observable factors but also by unobservable, latent factors.

▸The factors prioritized when choosing a place to live change as a result of shifts in personal values and life stages.

ex）People who prioritize convenience are more likely to move to urban areas; those who value community ties tend to stay in the same area; having school-age children makes moving difficult, etc.

Data

- Individual Attributes

Tohoku_History (Data: 4,000 individuals, 80,000 moves)

- Tax revenue by municipality (ratio relative to 2010 levels)

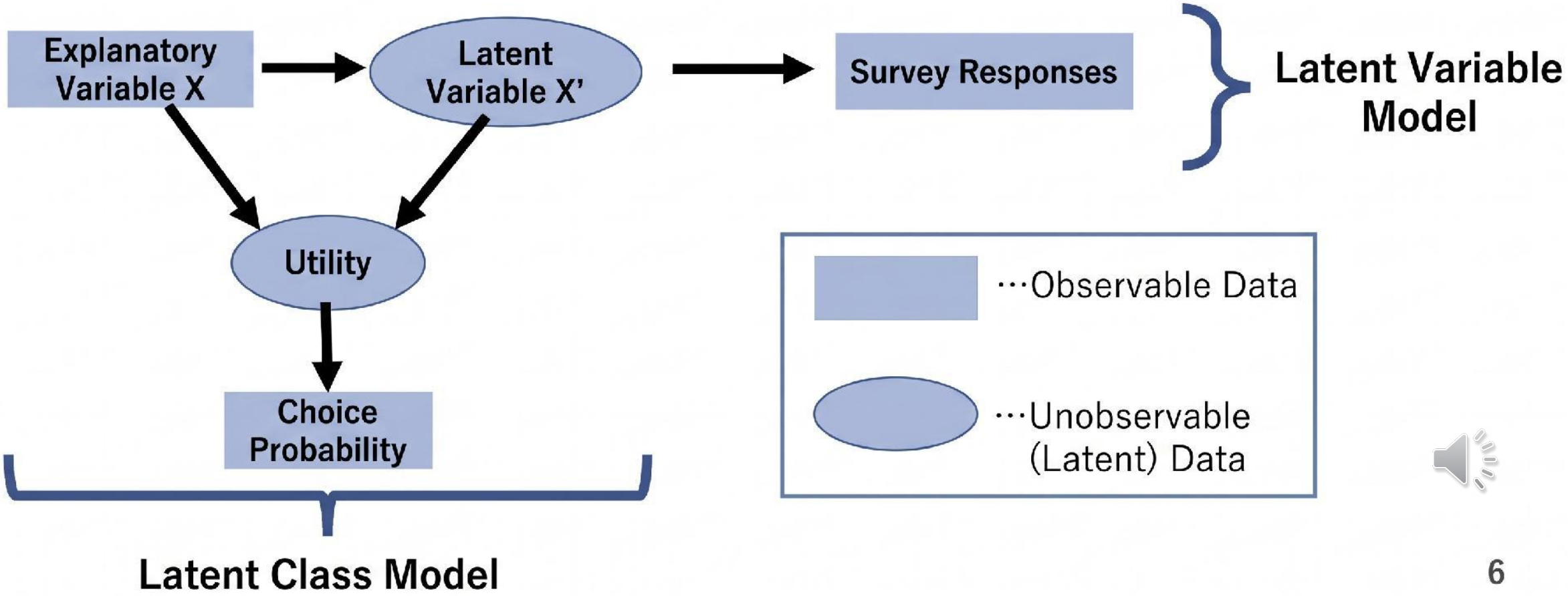
Ministry of Internal Affairs and Communications:
Survey on Settlement Status by Municipality
(Proxy variable for recovery status)

- Inter-municipal distance

Geopy (latitude/longitude)
Geodesic (distance)

model

Integrated Choice and Latent Variable Model × Latent Class Model



Latent class model

- **Why we use ”LCM”?**

- **Standard single logit model:**

→Assumes everyone responds in the same way.

- **Reality:**

→Responses to recovery and income should vary from person to person...

Latent Class Model

→ Estimates unobserved heterogeneous mobility types from the data.

$$Pijt = \Sigma c\ P(c|Zi) \times P(j|c,Xijt)$$

i: Individual (Respondent)

j: Alternative / Choice option (e.g., specific mode of transportation, destination, reconstruction-related choice, etc.)

t: Choice situation / Time point (assuming panel data, etc., where the same individual makes multiple choices)

c: Latent class (Unobserved group / type)

P_{ijt}: Final probability of individual i choosing alternative j in situation t

Utility function

Continue living in the same place

$$V_{it,\text{stay},k} = \beta_{1k}\widetilde{dist}_{it,\text{stay}} + \beta_{2k}\widetilde{income}_{it,\text{stay}} + \beta_{4k}\widetilde{tax}_{it,\text{stay}}$$

Move to another area

$$V_{itjk} = ASC_{jk} + \beta_{1k}\widetilde{dist}_{itj} + \beta_{2k}\widetilde{income}_{itj} + \beta_{3k}\widetilde{keika}_{itj} + \beta_{4k}\widetilde{tax}_{itj} + \lambda_{1k}X^*_{1i} + \lambda_{2k}X^*_{2i} + (\lambda_{3k} + \delta_j)X^*_{3i}, \qquad j \neq \text{stay}$$

Variable Definitions

- V_{itjk}: Observable utility of alternative j for individual i at time t, conditional on latent class k
- ASC_{jk}: Alternative-specific constant for alternative j in latent class k
- $\widetilde{dist}_{itj}$: Standardized distance associated with alternative j
- $\widetilde{income}_{itj}$: Standardized regional income associated with alternative j
- $\widetilde{keika}_{itj}$: Standardized years since 2010 × non-stay indicator
- $\widetilde{tax}_{itj}$: Standardized local tax recovery rate associated with alternative j
- β_{1k}: Distance coefficient for latent class k
- β_{2k}: Regional income coefficient for latent class k
- β_{3k}: Years-since-2010 coefficient for latent class k
- β_{4k}: Local tax recovery rate coefficient for latent class k
- X^*_{1i}: Latent variable related to life stage
- X^*_{2i}: Latent variable related to career and employment
- X^*_{3i}: Latent variable related to disaster-related factors
- λ_{1k}: Effect of X^*_1 on the utility of non-stay alternatives in latent class k
- λ_{2k}: Effect of X^*_2 on the utility of non-stay alternatives in latent class k
- λ_{3k}: Common effect of X^*_3 on the utility of non-stay alternatives in latent class k
- δ_j: Destination-specific deviation in the effect of X^*_3 for alternative j
- i: Individual
- t: Time period
- j: Residential location alternative
- k: Latent class

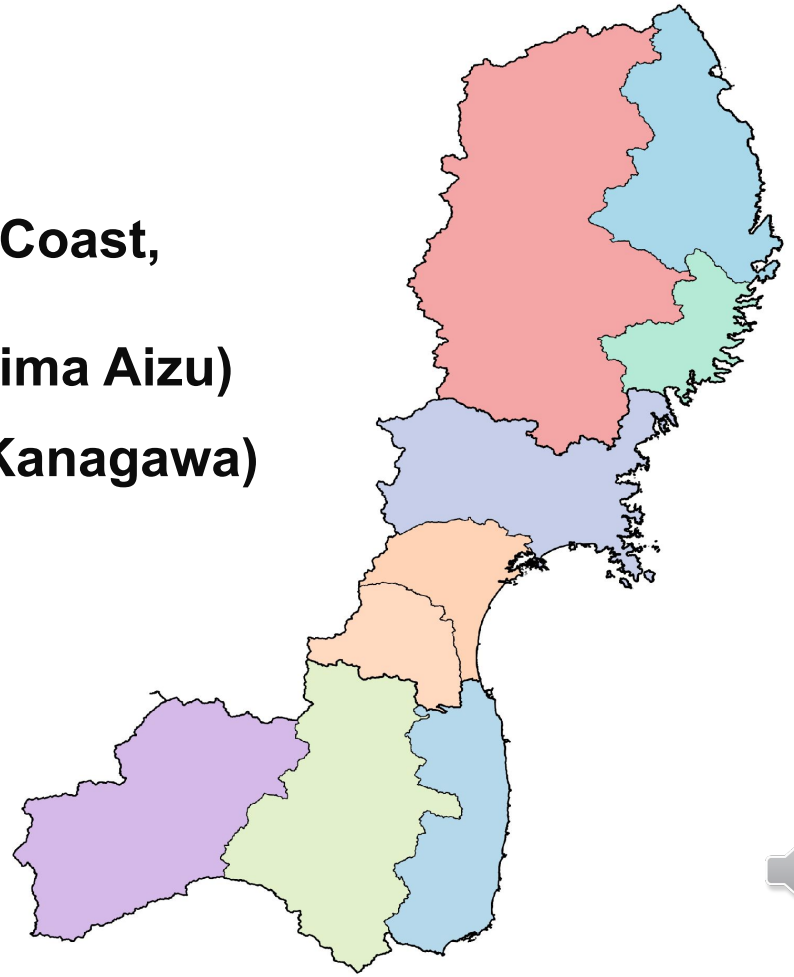
Dependent variable

- Continuing to reside in the same region
- 9 areas within the three Tohoku prefectures

→Japan Meteorological Agency classifications:
(Iwate Inland, Northern Iwate Coast, Southern Iwate Coast,
Sendai, North of Sendai, South of Sendai,
Fukushima Nakadori, Fukushima Hamadori, Fukushima Aizu)

- Tokyo Metropolitan Area (Tokyo, Saitama, Chiba, Kanagawa)

→ Total of 11 categories



Behaviour model variable

- **Membership covariates**

Age, Gender, Presence of children aged 0–6, Presence of children aged 7–18, Disaster victim flag

- **Variables of choice explanatory**

Distance, taxable income per capita, years elapsed since 2010, recovery rate of local taxes relative to FY2010

X_1: Life Stage Changes
X_2: Career Changes
X3：Disaster Risk Perception

Latent Class Profiles

Class	Characteristics	N	Share	Relocation	Reloc. year	Disaster	Age	Male	Income	Child 0-6	Child 7-18
1	Young + high income	846	0.32	0.46	2016.38	0.25	48.90	0.62	0.33	0.19	0.09
2	Stable stayer	1299	0.48	0.04	2018.80	0.00	59.27	0.77	0.26	0.08	0.21
3	Young mover	467	0.17	0.54	2016.26	0.28	48.10	0.60	0.29	0.18	0.09
4	High-income parent	71	0.03	1.00	2011.93	0.35	51.00	0.79	0.39	0.25	0.07

Destination Choice Shares by Latent Class

Class	Type	Stay	Sendai	Tokyo	Other 8 areas
1	Sendai-oriented	0.54	0.22	0.00	0.24
2	Stable stayer	0.96	0.00	0.00	0.04
3	Regional mover	0.46	0.00	0.00	0.53
4	Tokyo-oriented	0.00	0.08	0.75	0.17

C1: Young, High-Income Sendai-Oriented Movers
C2: Stable Stayers
C3: Young Regional Movers
C4: High-Income, Family-Oriented Tokyo Movers

Class-Specific Choice Model Results

Variable	C1 Sendai-oriented	C2 Stable stayer	C3 Regional mover	C4 Tokyo-oriented
Distance	−7.861*	−6.426*	−4.025*	+0.325*
Income Difference	+0.287*	+3.893*	+2.645*	0.706
Recovery Difference	+0.174*	0.449	−0.200*	−0.333
Years after 2010	−0.125	0.169	−0.019	−3.497

* p<0.05

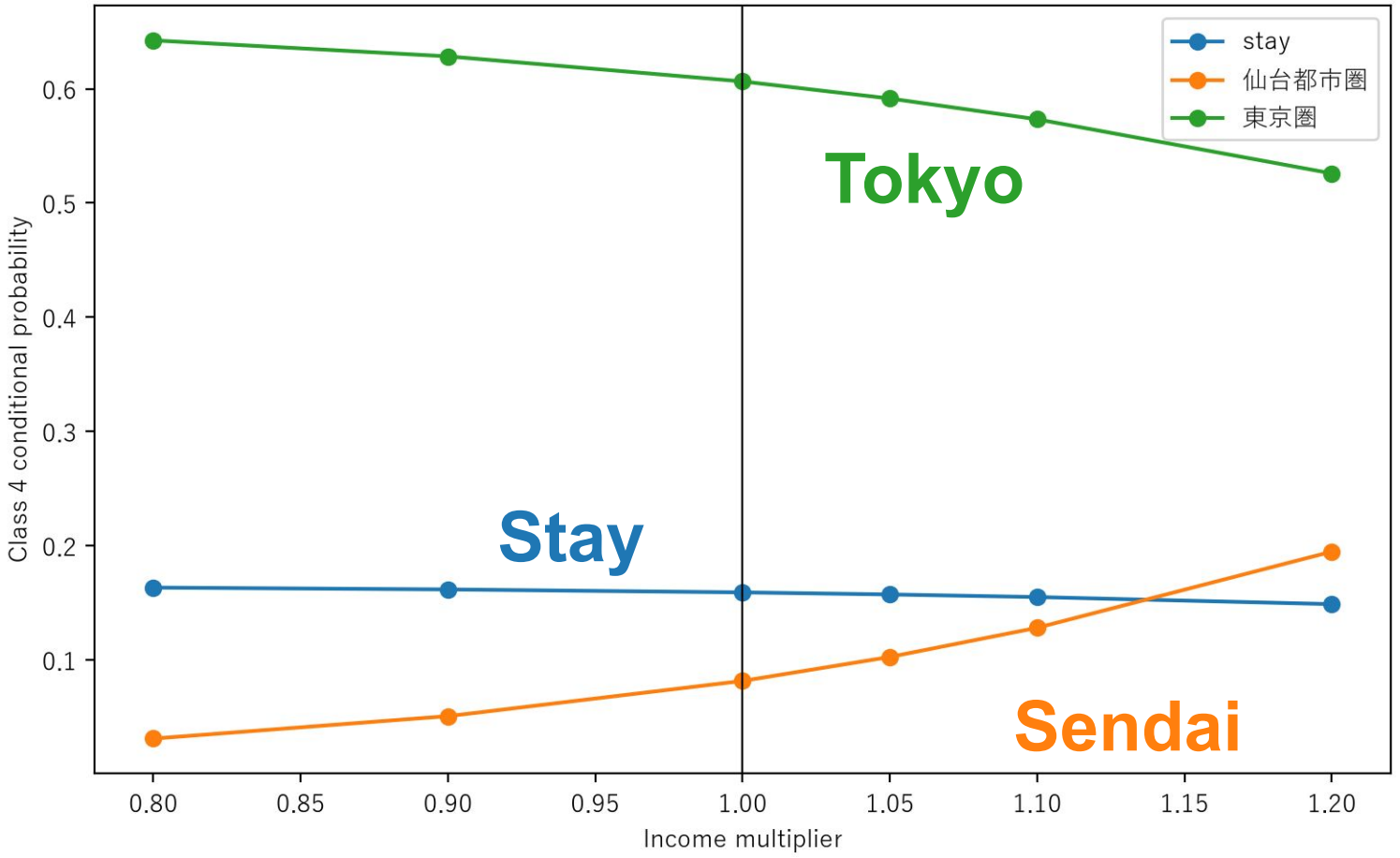
Policy Simulation

Policy simulation: recovery shortfall reduction

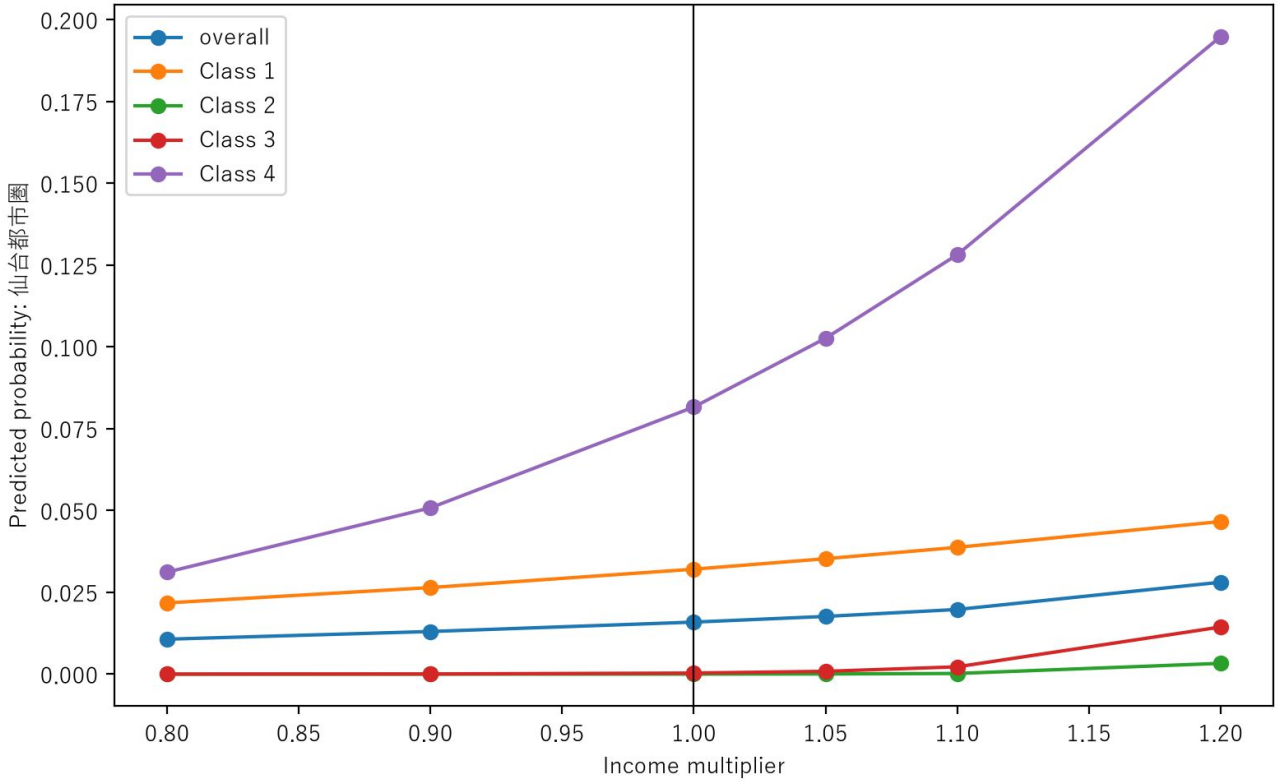
Recovery Shortfall Reduction	Sendai Choice Probability	Relative Change
0%	1.59%	0%
25%	1.61%	1.36%
50%	1.64%	2.80%
75%	1.66%	4.31%
100%	1.68%	5.89%

Policy Simulation: Income Level in Sendai

Destination Substitution within the Tokyo-Oriented Class(C4)



Sensitivity of Sendai Choice Probability to Regional Income Level



Tokyo-oriented class(C4) is highly responsive to higher income levels in Sendai

appendix

Additional Result(ICLV)

model_name	TsukubaF ICLV-LCCM
classes	3
n_person	2596
n_situations	36404
n_choice_rows	400444
n_measurement_events	2363
n_parameters	122
log_likelihood	-9463.31656
AIC	19170.633120135142
BIC_person_level	19885.763823629666
optimizer_success	FALSE
optimizer_message	STOP: TOTAL NO. OF ITERATIONS REACHED LIMIT
optimizer_iterations	1200
gradient_inf_norm	0.226314786798045 73

model_name	TsukubaF ICLV-LCCM
n_draws_train	128
n_draws_unpenalized	128
n_draws_final	256
BHHH_rank	107
BHHH_rank_deficiency	15
BHHH_condition_number	4717789873
BHHH_eigen_tol	3.152110931073179e-06
n_bad_or_nan_se	0
inference_reliable	FALSE

Additional Result(ICLV)

Explanatory Variable / Attribute	Class 1 (Est. / SE / t)	Class 2 (Est. / SE / t)	Class 3 (Est. / SE / t)
Tokyo Dummy (ASC_tokyo)	+0.331*** (0.004) [t=+82.33]	-12.906*** (0.748) [t=-17.26]	-3.306 (3.539) [t=-0.93]
Distance (std)	-9.491*** (2.542) [t=-3.73]	-1.767*** (0.181) [t=-9.75]	-0.041 (0.192) [t=-0.21]
Regional Income (std)	+0.243 (0.559) [t=+0.43]	+1.013*** (0.156) [t=+6.49]	+0.438 (0.280) [t=+1.56]
Elapsed Years (std)	-0.345* (0.145) [t=-2.38]	-0.385*** (0.063) [t=-6.13]	-0.172 (0.207) [t=-0.83]
Local Tax Recovery Rate (std)	+0.336*** (0.004) [t=+79.13]	+0.412*** (0.013) [t=+31.93]	+0.309*** (0.025) [t=+12.36]

Additional Result(ICLV)

Latent Variable	Explanatory Factor / Term	Estimate (γ)	Std. Error	t-value	p-value
X1_lifestage	intercept	**-1.5153**	12.0279	-0.13	0.8997
X1_lifestage	old	**-0.5357*** **	0.0679	-7.90	0.0000
X1_lifestage	gender	**+0.1987*** **	0.0597	+3.33	0.0009
X1_lifestage	child1_age_0_to_6_flag	**+0.0590**	0.0407	+1.45	0.1466
X1_lifestage	child1_age_7_to_18_flag	**+0.0175**	0.0548	+0.32	0.7487
X1_lifestage	years_since_first_marry	**-0.0341**	0.0733	-0.46	0.6422
X1_lifestage	time_series_house_member_num	**+0.2123** **	0.0653	+3.25	0.0012
X1_lifestage	marry	**+0.4255*** **	0.0420	+10.13	0.0000
X1_lifestage	birth	**+0.0152**	0.0355	+0.43	0.6676
X1_lifestage	divorce	**+0.0206**	0.0397	+0.52	0.6043
X1_lifestage	sep	**+0.1153**	0.0610	+1.89	0.0586
X1_lifestage	time_series_dummy_owned	**+0.0900**	0.1323	+0.68	0.4963
X1_lifestage	time_series_dummy_rented	**-0.0720**	0.1312	-0.55	0.5831
X1_lifestage	time_series_dummy_evacuated	**-0.1598**	0.1296	-1.23	0.2174
X2_career_env	intercept	**-2.0418**	27.7002	-0.07	0.9412
X2_career_env	years_since_first_job	**-0.1060***	0.0426	-2.49	0.0129
X2_career_env	job	**+0.1994*** **	0.0323	+6.18	0.0000
X2_career_env	retirement	**+0.1232*** **	0.0229	+5.37	0.0000
X2_career_env	transfer	**+0.2685*** **	0.0171	+15.72	0.0000
X3_disaster	intercept	**-8.1844** **	2.8417	-2.88	0.0040
X3_disaster	old	**-0.0296**	0.0458	-0.65	0.5180
X3_disaster	hisaisha_flag	**+0.0668**	0.0412	+1.62	0.1046
X3_disaster	years_since_2011	**-0.1988*** **	0.0420	-4.73	0.0000
X3_disaster	has_child_flag	**+0.0569**	0.0409	+1.39	0.1647
X3_disaster	O_flooding_rate	**+0.1685*** **	0.0350	+4.82	0.0000

Additional Result(ICLV)

Target Class	Predictor Term	Estimate (θ)	Std. Error	t-value	p-value
Class 2	intercept	**+0.5394**	12.6298	+0.04	0.9659
Class 2	old_std	**-0.9181*** **	0.1959	-4.69	0.0000
Class 2	gender_std	**+0.1847**	0.1432	+1.29	0.1969
Class 2	child1_age_0_to_6_flag_std	**+0.1741**	0.1302	+1.34	0.1811
Class 2	child1_age_7_to_18_flag_std	**-0.4633**	0.5171	-0.90	0.3702
Class 2	hisaisha_flag_std	**-0.1697**	0.1351	-1.26	0.2091
Class 2	X1_lifestage	**-0.6541***	0.2574	-2.54	0.0110
Class 2	X2_career_env	**+0.1946**	0.2691	+0.72	0.4697
Class 2	X3_disaster	**+0.2324**	0.3009	+0.77	0.4398
Class 3	intercept	**+0.4486**	17.9359	+0.03	0.9800
Class 3	old_std	**-1.1151*** **	0.1981	-5.63	0.0000
Class 3	gender_std	**-0.1230**	0.1429	-0.86	0.3892
Class 3	child1_age_0_to_6_flag_std	**+0.1179**	0.1272	+0.93	0.3541
Class 3	child1_age_7_to_18_flag_std	**-0.4130**	0.7199	-0.57	0.5662
Class 3	hisaisha_flag_std	**+0.3143**	0.1748	+1.80	0.0722
Class 3	X1_lifestage	**-0.2637**	0.2805	-0.94	0.3471
Class 3	X2_career_env	**+0.5584** **	0.2130	+2.62	0.0088
Class 3	X3_disaster	**+0.3093**	0.2946	+1.05	0.2938

メイン比較表：対象5自治体における所得支援（+50万円）効果

自治体	サンプル数 (n)	基準転出確率	所得+50万円後	Δ転出確率	基準滞在確率	政策後滞在確率	Δ滞在確率
仙台市	564	1.28%	$\approx$0%	-1.28 **pt**	98.31%	$\approx$100%	$+1.70$ **pt**
気仙沼市	24	2.25%	$\approx$0%	-2.25 **pt**	95.20%	$\approx$100%	$+4.80$ **pt**
南三陸町 $\ast$	1	1.02%	$\approx$0%	-1.02 **pt**	96.77%	$\approx$100%	$+3.23$ **pt**
山田町 $\ast$	5	0.26%	$\approx$0%	-0.26 **pt**	96.76%	$\approx$100%	$+3.24$ **pt**
南相馬市	22	0.63%	$\approx$0%	-0.63 **pt**	97.47%	$\approx$100%	$+2.53$ **pt**

$\ast$ **注記**: 南三陸町（$n=1$）、山田町（$n=5$）は対象状況数が極めて少ないため、自治体間の効果量の単純比較には留意が必要。

現時点の推定結果（暫定）と解釈

ICLV-LCCM（3クラス）／N=2,596人，36,404選択時点
※ 最適化は iteration limit で停止しており，以下は暫定的な解釈

潜在クラスの概要

Class	Share	主な行動パターン	解釈
C1	78.7%	Stay 95.5%, Sendai 3.3%	定住中心クラス
C2	17.2%	Stay 35.3%, 東北域内へ分散移動	東北域内移動クラス
C3	4.0%	Tokyo 90.5%, Sendai 4.8%	東京志向クラス

読み取れること

- サンプルは主に 3 つの移動タイプに分かれ，多数派は“同一地域にとどまる”傾向を示す。
- 一方で，若年層を中心に東北域内で再配置する層と、少数だが東京への強い志向を持つ層が確認される。
- クラス所属モデルでは，年齢が高いほど C2・C3 に属しにくく，若年層ほど移動志向が強いことが示唆される。

主要説明変数の効果（有意なもの中心）

変数	C1	C2	C3
距離	−	−	n.s.
所得	n.s.	+	n.s.
地方税回復率	+	+	+
経過年数	−	−	n.s.

暫定結果では，復興の進んだ地域ほど選ばれやすく，距離抵抗は主に C1・C2 で強い。少数ながら C3 には広域移動（東京志向）の存在が見られる。

効用関数

同じ場所に居住し続ける（taizai）

$$V_{it,\text{taizai},k} = \beta_{1k}\widetilde{dist}_{it,\text{taizai}} + \beta_{2k}\widetilde{income}_{it,\text{taizai}} + \beta_{3k}\widetilde{keika}_{it,\text{taizai}} + \beta_{4k}\widetilde{tax}_{it,\text{taizai}}$$

岩手県内陸部（iwate_riku）

$$\begin{aligned} V_{it,\text{iwate\_riku},k} = {} & ASC_{\text{iwate\_riku},k} + \beta_{1k}\widetilde{dist}_{it,\text{iwate\_riku}} + \beta_{2k}\widetilde{income}_{it,\text{iwate\_riku}} \\ & + \beta_{3k}\widetilde{keika}_{it,\text{iwate\_riku}} + \beta_{4k}\widetilde{tax}_{it,\text{iwate\_riku}} \\ & + \lambda_{1k}X^*_{1i} + \lambda_{2k}X^*_{2i} + \lambda_{3k}X^*_{3i} \end{aligned}$$

. 岩手県沿岸北部（iwate_umi_north）

$$\begin{aligned} V_{it,\text{iwate\_umi\_north},k} = {} & ASC_{\text{iwate\_umi\_north},k} + \beta_{1k}\widetilde{dist}_{it,\text{iwate\_umi\_north}} + \beta_{2k}\widetilde{income}_{it,\text{iwate\_umi\_north}} \\ & + \beta_{3k}\widetilde{keika}_{it,\text{iwate\_umi\_north}} + \beta_{4k}\widetilde{tax}_{it,\text{iwate\_umi\_north}} \\ & + \lambda_{1k}X^*_{1i} + \lambda_{2k}X^*_{2i} + \left(\lambda_{3k} + \delta_{\text{iwate\_umi\_north}}\right)X^*_{3i} \end{aligned}$$

. 岩手県沿岸南部（iwate_umi_south）

$$\begin{aligned} V_{it,\text{iwate\_umi\_south},k} = {} & ASC_{\text{iwate\_umi\_south},k} + \beta_{1k}\widetilde{dist}_{it,\text{iwate\_umi\_south}} + \beta_{2k}\widetilde{income}_{it,\text{iwate\_umi\_south}} \\ & + \beta_{3k}\widetilde{keika}_{it,\text{iwate\_umi\_south}} + \beta_{4k}\widetilde{tax}_{it,\text{iwate\_umi\_south}} \\ & + \lambda_{1k}X^*_{1i} + \lambda_{2k}X^*_{2i} + \left(\lambda_{3k} + \delta_{\text{iwate\_umi\_south}}\right)X^*_{3i} \end{aligned}$$

仙台・宮城中央部（sendai_center）

$$\begin{aligned} V_{it,\text{sendai\_center},k} = {} & ASC_{\text{sendai\_center},k} + \beta_{1k}\widetilde{dist}_{it,\text{sendai\_center}} + \beta_{2k}\widetilde{income}_{it,\text{sendai\_center}} \\ & + \beta_{3k}\widetilde{keika}_{it,\text{sendai\_center}} + \beta_{4k}\widetilde{tax}_{it,\text{sendai\_center}} \\ & + \lambda_{1k}X^*_{1i} + \lambda_{2k}X^*_{2i} + \left(\lambda_{3k} + \delta_{\text{sendai\_center}}\right)X^*_{3i} \end{aligned}$$

宮城県北部（sendai_north）

$$\begin{aligned} V_{it,\text{sendai\_north},k} = {} & ASC_{\text{sendai\_north},k} + \beta_{1k}\widetilde{dist}_{it,\text{sendai\_north}} + \beta_{2k}\widetilde{income}_{it,\text{sendai\_north}} \\ & + \beta_{3k}\widetilde{keika}_{it,\text{sendai\_north}} + \beta_{4k}\widetilde{tax}_{it,\text{sendai\_north}} \\ & + \lambda_{1k}X^*_{1i} + \lambda_{2k}X^*_{2i} + \left(\lambda_{3k} + \delta_{\text{sendai\_north}}\right)X^*_{3i} \end{aligned}$$

宮城県南部（sendai_south）

$$\begin{aligned} V_{it,\text{sendai\_south},k} = {} & ASC_{\text{sendai\_south},k} + \beta_{1k}\widetilde{dist}_{it,\text{sendai\_south}} + \beta_{2k}\widetilde{income}_{it,\text{sendai\_south}} \\ & + \beta_{3k}\widetilde{keika}_{it,\text{sendai\_south}} + \beta_{4k}\widetilde{tax}_{it,\text{sendai\_south}} \\ & + \lambda_{1k}X^*_{1i} + \lambda_{2k}X^*_{2i} + \left(\lambda_{3k} + \delta_{\text{sendai\_south}}\right)X^*_{3i} \end{aligned}$$

福島県浜通り（fukushima_hama）

$$\begin{aligned} V_{it,\text{fukushima\_hama},k} = {} & ASC_{\text{fukushima\_hama},k} + \beta_{1k}\widetilde{dist}_{it,\text{fukushima\_hama}} + \beta_{2k}\widetilde{income}_{it,\text{fukushima\_hama}} \\ & + \beta_{3k}\widetilde{keika}_{it,\text{fukushima\_hama}} + \beta_{4k}\widetilde{tax}_{it,\text{fukushima\_hama}} \\ & + \lambda_{1k}X^*_{1i} + \lambda_{2k}X^*_{2i} + \left(\lambda_{3k} + \delta_{\text{fukushima\_hama}}\right)X^*_{3i} \end{aligned}$$

福島県中通り（fukushima_naka）

$$\begin{aligned} V_{it,\text{fukushima\_naka},k} = {} & ASC_{\text{fukushima\_naka},k} + \beta_{1k}\widetilde{dist}_{it,\text{fukushima\_naka}} + \beta_{2k}\widetilde{income}_{it,\text{fukushima\_naka}} \\ & + \beta_{3k}\widetilde{keika}_{it,\text{fukushima\_naka}} + \beta_{4k}\widetilde{tax}_{it,\text{fukushima\_naka}} \\ & + \lambda_{1k}X^*_{1i} + \lambda_{2k}X^*_{2i} + \left(\lambda_{3k} + \delta_{\text{fukushima\_naka}}\right)X^*_{3i} \end{aligned}$$

福島県会津（fukushima_aizu）

$$\begin{aligned} V_{it,\text{fukushima\_aizu},k} = {} & ASC_{\text{fukushima\_aizu},k} + \beta_{1k}\widetilde{dist}_{it,\text{fukushima\_aizu}} + \beta_{2k}\widetilde{income}_{it,\text{fukushima\_aizu}} \\ & + \beta_{3k}\widetilde{keika}_{it,\text{fukushima\_aizu}} + \beta_{4k}\widetilde{tax}_{it,\text{fukushima\_aizu}} \\ & + \lambda_{1k}X^*_{1i} + \lambda_{2k}X^*_{2i} + \left(\lambda_{3k} + \delta_{\text{fukushima\_aizu}}\right)X^*_{3i} \end{aligned}$$

東京（tokyo）

$$\begin{aligned} V_{it,\text{tokyo},k} = {} & ASC_{\text{tokyo},k} + \beta_{1k}\widetilde{dist}_{it,\text{tokyo}} + \beta_{2k}\widetilde{income}_{it,\text{tokyo}} \\ & + \beta_{3k}\widetilde{keika}_{it,\text{tokyo}} + \beta_{4k}\widetilde{tax}_{it,\text{tokyo}} \\ & + \lambda_{1k}X^*_{1i} + \lambda_{2k}X^*_{2i} + \left(\lambda_{3k} + \delta_{\text{tokyo}}\right)X^*_{3i} \end{aligned}$$

Structural Equation for Latent Variables

- Describes causal relationships between variables via the latent variable X^*

$$X^* = h(X;\gamma) + \eta \ \ and\ \eta \sim D(0, \sum_\eta)$$

- Represents the process by which objective attributes, environments, and experiences (X) shape human internal psychology and values (X^*)

X： Observable explanatory variable

γ： Sensitivity of each variable toward psychological formation

X^*： Latent variable (probability distribution)

η： Error term (probability distribution)

Measurement Equation for Latent Variables

- Describes the relationship where unobservable latent variable X^* manifests as observable indicators

$$I = g(X, X^*; \alpha) + v \; and \; v \sim D(0, \sum_v^*)$$
$$= \Phi(\alpha_0 + \alpha \cdot X^*) + v \; and \; v \sim D(0, \sum_v^*)$$

※Since the survey response is binary data of "0 or 1 (whether a reason was selected)", $g(\cdot)$ is formulated as a binary probit model.

- Models how latent consciousness is reflected as observable responses (measurement indicators I)

I : Measurement indicator (survey data)　　X^* : Latent variable

X : Observable explanatory variable　$g(\cdot)$: Measurement function (binary probit)

α : Measurement parameter　　v : Measurement error term

Measurement Equation for Latent Variables

- Describes the relationship where unobservable latent variable X^* manifests as observable indicators

$$I = g(X, X^*; \alpha) + v \; and \; v \sim D(0, \sum_v^*)$$
$$= \Phi(\alpha_0 + \alpha \cdot X^*) + v \; and \; v \sim D(0, \sum_v^*)$$

※Since the survey response is binary data of "0 or 1 （whether a reason was selected）",$g(\cdot)$is formulated as a binary probit model.

- Fixing the sensitivity α to 1.0 for a specific survey question I_1 assigns a statistical and physical unit (scale) to the latent variable X^*, which lacks a physical unit.

Definition of Latent Variables

- X_1: Life Stage Changes

Indicates psychological sensitivity to life stage changes

- X_2: Career Changes

Indicates psychological sensitivity to career changes

- X_3: Disaster Risk Perception

Indicates psychological sensitivity to disaster risks

Definition of Latent Variables

- X_1: Life Stage Changes

Indicates psychological sensitivity to life stage changes

Explanatory variables (Connected variables) :
Age, Gender, Flag for having children aged 0–6,
Flag for having children aged 7–18,
Years elapsed since marriage, Household size at relocation,
Marriage event, Birth of a child event, Divorce event,
Child moving out event, Housing type

Definition of Latent Variables

- X_2: Career Changes

Indicates psychological sensitivity to career changes

Explanatory variables (Connected variables):

Years elapsed since events such as employment or job change, Employment or job change event, Retirement event, Job transfer event

- X_3: Disaster Risk Perception

Indicates psychological sensitivity to disaster risks

Explanatory variables (Connected variables):

Age, Flag for having children, Disaster victim flag, Years elapsed since 2011

Indicators of Latent Variables

X1：Life Stage Changes

- Household division / independence due to marriage, etc.
- Child growth / birth
- Co-residence, household division, or independence with parents or children
- Divorce from or bereavement of spouse

Indicators of Latent Variables

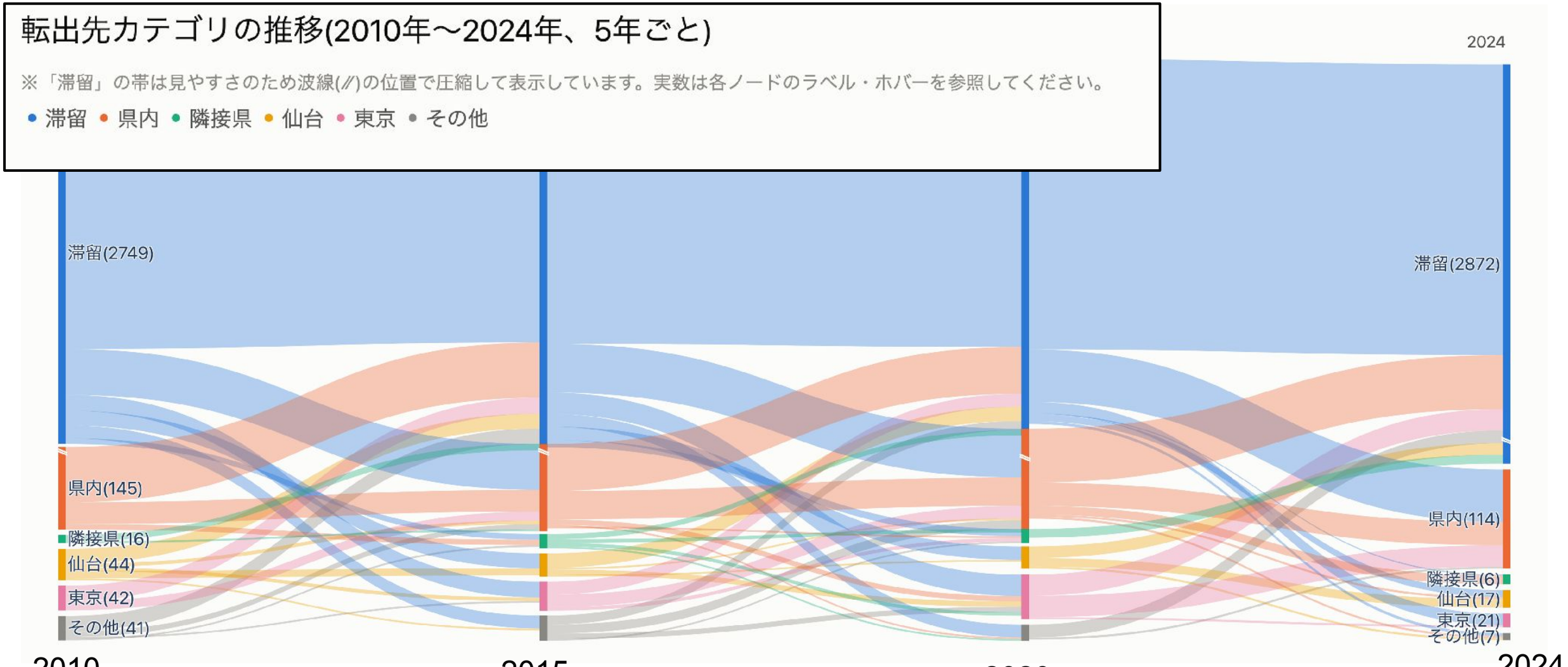
X2：Career Changes

- One's own higher education, employment, job transfer, career change, or retirement
- Spouse's higher education, employment, job transfer, career change, or retirement
- Dissatisfaction with housing environment ・Dissatisfaction with residential area
- Financial reasons

X3：Disaster Risk Perception

- Disaster-related reasons
- Others

2010年以降
サンキーダイアグラム（滞留、県内、隣接県、仙台、東京　）



エリア別出発地・到着地レコード数

表1　エリア別の出発地・到着地レコード数(person-year)

地域区分	エリア(10区分)	出発地 (人年)	出発 構成比	到着地 (人年)	到着 構成比
東北3県	岩手県	11,833	19.5%	11,676	19.2%
東北3県	宮城県(仙台市)	12,219	20.1%	12,056	19.8%
東北3県	宮城県(仙台市以外)	10,431	17.2%	10,286	16.9%
東北3県	福島県	17,649	29.1%	17,359	28.6%
対象外	茨城県	669	1.1%	728	1.2%
東京圏	埼玉県	1,163	1.9%	1,245	2.0%
東京圏	千葉県	886	1.5%	959	1.6%
東京圏	東京都(特別区)	3,486	5.7%	3,822	6.3%
東京圏	東京都(多摩)	1,162	1.9%	1,265	2.1%
東京圏	神奈川県	1,242	2.0%	1,344	2.2%
— 小計 —	東北3県 計	52,132	85.8%	51,377	84.6%
— 小計 —	東京圏(1都3県) 計	7,939	13.1%	8,635	14.2%
— 小計 —	対象外(茨城) 計	669	1.1%	728	1.2%

潜在変数

$$X^*_{\text{lifestage}} = -0.2750 - 0.0474 \cdot X_{\text{old}} + 0.0226 \cdot X_{\text{gender}} + 0.0087 \cdot X_{\text{child num}} - 0.0560 \cdot X_{\text{child1 age 0 to 6 flag}} - 0.0005 \cdot X_{\text{child1 age 7 to 18 flag}} - 0.0705 \cdot X_{\text{years since first birth}} + 0.0285 \cdot X_{\text{years since first marry}} + 0.3700 \cdot X_{\text{marry}} - 0.0233 \cdot X_{\text{birth}} + 0.2033 \cdot X_{\text{divorce}} + 0.1306 \cdot X_{\text{sep}}$$

$$X^*_{\text{career env}} = -0.4505 + 0.0001 \cdot X_{\text{any relocation income}} - 0.0139 \cdot X_{\text{years since first job}} + 0.1852 \cdot X_{\text{job}} + 0.1252 \cdot X_{\text{retirement}} + 0.7233 \cdot X_{\text{transfer}} - 0.0028 \cdot X_{\text{pref distance}} - 0.0125 \cdot X_{\text{neig distance}} - 0.0014 \cdot X_{\text{sendai distance}} + 0.0016 \cdot X_{\text{toukyou distance}}$$

$$X^*_{\text{disaster}} = -1.6292 + 0.7445 \cdot X_{\text{disaster flag}} + 0.0772 \cdot X_{\text{years since 2011}}$$

測定方程式

$$I_{\text{reason 1}} = 0.5393$$
$$I_{\text{reason 2}} = -0.9053 + 0.1761 \cdot X^*_{\text{lifestage}}$$
$$I_{\text{reason 3}} = 0.5179$$
$$I_{\text{reason 4}} = -1.1062 + 0.2253 \cdot X^*_{\text{career env}}$$
$$I_{\text{reason 5}} = -1.1158 + 0.3496 \cdot X^*_{\text{lifestage}}$$
$$I_{\text{reason 6}} = -1.1558 + 0.7584 \cdot X^*_{\text{lifestage}}$$
$$I_{\text{reason 7}} = -1.0825 + 0.2562 \cdot X^*_{\text{career env}}$$
$$I_{\text{reason 8}} = -1.1762 + 0.7980 \cdot X^*_{\text{career env}}$$
$$I_{\text{reason 9}} = -1.1696 + 0.3489 \cdot X^*_{\text{career env}}$$
$$I_{\text{reason 10}} = -1.5873$$
$$I_{\text{reason 11}} = -1.4719 - 0.2217 \cdot X^*_{\text{disaster}}$$

1	結婚などによる世帯分離・独立
2	子供の成長・誕生
3	自身の進学・就職・転勤・転職・退職
4	配偶者の進学・就職・転勤・転職・退職
5	親または子どもとの同居・世帯分離・独立
6	配偶者との離別・死別
7	住宅環境への不満
8	居住地域への不満
9	経済的理由
10	災害に関係する理由
11	その他

相談したいことリスト

- 被説明変数の「同じ自治体に居住し続ける」に含まれる自治体ごとに、
  例えば仙台と気仙沼では、滞在することの意味付けが違うのではないか

エスキスメモ

- 年齢と性別の相互作用

- 政策シナリオ
- 年収を補助で上げてみる

- 居住している場所の規模の違いを入れたい
- 相対的な居住地の差をつけたい
- 人口密度、など

- 被説明変数がダブっている
- 場所と同じかどうかが
  移動先ととどまるが並列になっている
- 東日本_県をまたいでの移動が少ない
  残留、県外、自治体内、関東、ばどうか
- 出発地は東北に絞った方がいいかも
- その方が地域の特性が混ざりにくい、空間的な相関が入らないように
- 千葉に住んでて埼玉に引っ越すは別の要因ではないか、被害の程度が混ざってしまっている
- 被災した時の居住地を工夫するのがよさそう
- 前に住んでたところと相互作用？

2011年前と2011より後で、同じモデルを回してみる
サンキーダイアグラムの政策前と後があるといいかも、でも解釈するのムズイ、ちょっと見にくい？

被災した場所にい続ける、と、一回引っ越した後にい続ける、は別の意味かも

関係ない人が残留していることが含まれていると、モデルにバイアスがかかってしまう
差異がお前後の動きを見たいから、それに合わせてモデルを変更する必要がある
⇨最初のラベルのつけかたが大切

被説明変数

- 同じ自治体に居住し続ける
- 仙台都市圏
- 東京都市圏
- 県内
- 隣接県

残留・転居先の割合

sample	残留	仙台圏	東京圏	県内	隣接県	その他
all	69.7%	3.8%	16.4%	6.7%	2.0%	1.4%
disaster	43.9%	8.8%	25.6%	13.2%	7.1%	1.5%
non_disaster	73.8%	3.0%	15.0%	5.6%	1.2%	1.4%

潜在変数の構造方程式

- 潜在変数X^*を介した、変数間の因果関係を記述

$$X^* = h(X;\gamma) + \eta \ \ and\ \eta \sim D(0, \sum_\eta)$$

- 客観的な属性や環境・経験（X）が、人間の内面的心理・価値観（X^*）を形作るプロセスを示す

X　　：観測可能な説明変数 γ：各変数の心理形成への感度を示す

X^*　　：潜在変数(確率分布) η：誤差項(確率分布)

潜在変数の測定方程式

- 直接見えない潜在変数X^*が、観察可能な指標として現れる関係を記述

$$I = g(X, X^*; \alpha) + v \; and \; v \sim D(0, \sum_v^*)$$
$$= \Phi(\alpha_0 + \alpha \cdot X^*) + v \; and \; v \sim D(0, \sum_v^*)$$

※アンケート回答が「0 または 1（理由を選んだか否か）」の2値データなので、$g(\cdot)$は二項プロビットモデルとして展開

- 潜在意識が観測可能な応答(測定指標I)としてどのように表出されるかをモデル化する

I ：測定指標(アンケートデータ)　X^* ：潜在変数

X：観測可能な説明変数　$g(\cdot)$ ：測定関数(2項プロビット)

α：測定パラメータ　v ：測定誤差項

潜在変数の測定方程式

- 直接見えない潜在変数X^*が、観察可能な指標として現れる関係を記述

$$I = g(X, X^*; \alpha) + v \; and \; v \sim D(0, \sum_v^*)$$
$$= \Phi(\alpha_0 + \alpha \cdot X^*) + v \; and \; v \sim D(0, \sum_v^*)$$

※アンケート回答が「0 または 1（理由を選んだか否か）」の2値データなので、$g(\cdot)$は二項プロビットモデルとして展開

- 物理的単位を持たない潜在変数X^*に対し、特定のアンケート設問I_1の感度αを1.0に固定することで、潜在変数に統計的・物理的な単位（尺度）を与える役割を果たす

潜在変数の定義

- X1：ライフステージの変化
  ライフステージの変化に対する心理的感度を示す

- X2：キャリアの変化
  キャリアの変化に対する心理的感度を示す

- X3：災害リスク認知
  災害リスクに対する心理的感度を示す

潜在変数の定義

- X1：ライフステージの変化

  ライフステージの変化に対する心理的感度を示す

接続変数：

年齢、性別、0~6歳子持ちフラグ、7~18歳子持ちフラグ、結婚経過年、転居時の世帯人数、結婚イベント、子の誕生イベント、離婚イベント、子の別居イベント、住居タイプ

潜在変数の定義

- X2：キャリアの変化

　キャリアの変化に対する心理的感度を示す

接続変数：

　就職や転職などのイベントからの経過年数、就職や転職などのイベント、退職イベント、転勤イベント

- X3：災害リスク認知

　災害リスクに対する心理的感度を示す

接続変数：

　年齢、子持ちフラグ、被災者フラグ、2011年からの経過年数

潜在変数の指標

X1：ライフステージの変化

- 結婚などによる世帯分離・独立
- 子供の成長・誕生
- 親または子どもとの同居・世帯分離・独立
- 配偶者との離別・死別

潜在変数の指標

X2：キャリアの変化

- 自身の進学・就職・転勤・転職・退職
- 配偶者の進学・就職・転勤・転職・退職
- 住宅環境への不満
- 居住地域への不満
- 経済的理由

X3：災害リスク認知

- 災害に関係する理由
- その他

結果

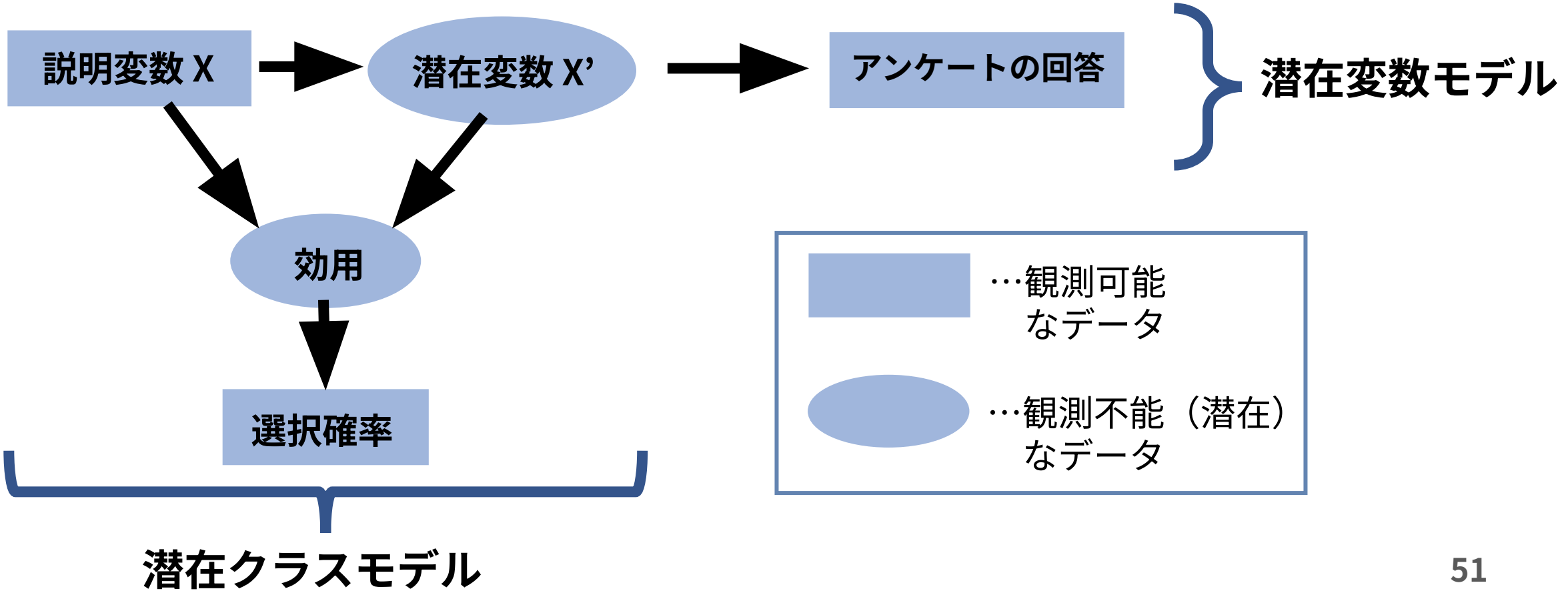
考察

政策シナリオ

政策シナリオ代入後の選択確率

使いたいモデル

Integrated of Choice and Latent Variable Model
統合選択と潜在変数モデル
×
Latent Class Model
潜在クラスモデル



Additional Result(ICLV)

Metric / Parameter	Value	Sample / Diagnostic Indicator	Value
Model Name	**TsukubaF ICLV-LCCM**	Target Sample (Persons)	**2,596**
Number of Classes	**3**	Choice Situations (Panel)	**36,404**
Number of Parameters	**122**	Choice Rows Evaluated	**400,444**
Log-Likelihood	**-9,463.32**	Measurement Events	**2,363**
AIC	**19,170.63**	Monte Carlo Draws (Train/Final)	**128 / 256**
BIC (Person-Level)	**19,885.76**	Gradient Norm (Inf Norm)	**0.2263**
Optimizer Status	**Stopped (Iter 1200)**	BHHH Rank Deficiency	**15 (Rank: 107)**
Inference Reliability	**Requires Caution (Unpenalized)**	Bad SE Count	**0**