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How accessibility shapes the landscape of car and season-ticket ownership: A bivariate probit approach

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Mobility tools

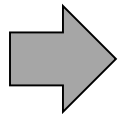
- Means to achieve mobility: Shoes, bicycles, motorbikes, driving licence, cars, public transport tickets, subscription to public transport etc. (Bundesamt für Raumentwicklung ARE, 2006)
- We focus on cars and season-ticket as both usually require large upfront investments
- Second important factor in choice: Travel time – but how to deal and explain choices in RP census data with travel time?

Accessibility

- Concept of accessibility
 - “*Generalization of the population-over-distance relationship*” (Hansen, 1959)
 - “*Accessibility can also be seen as an interface between (urban) economy and (transport) geography*” (Crozet et al., 2012)
- Households chose resident locations following their demand of accessibility (Kitamura et al., 2001; Axhausen and König, 2001)
- Long-term benefits of travel time savings (Metz, 2008)
- Measure of the generalized cost of travel (Weis and Axhausen, 2009)
- Positive relationship with agglomeration benefits (Axhausen et al., 2015)

Accessibility and mobility tool ownership

- Travel variables are generally inelastic with respect to change in measures of the built environment. vehicle miles traveled is most strongly related to measures of accessibility to destinations (Ewing and Cervero, 2010)
- Greater levels of public transport accessibility reduce ownership of a second/ third car per household (Van Eggermond et al., 2016) but also distance to the nearest bus stop (Kim and Kim, 2004)
- Accessibility is a measure of the generalized cost of travel (Weis and Axhausen, 2009)



Hypothesis: Travelers chose the mobility tools at comparative lower generalized cost of travel, i.e. greater levels of accessibility

Data

Household data

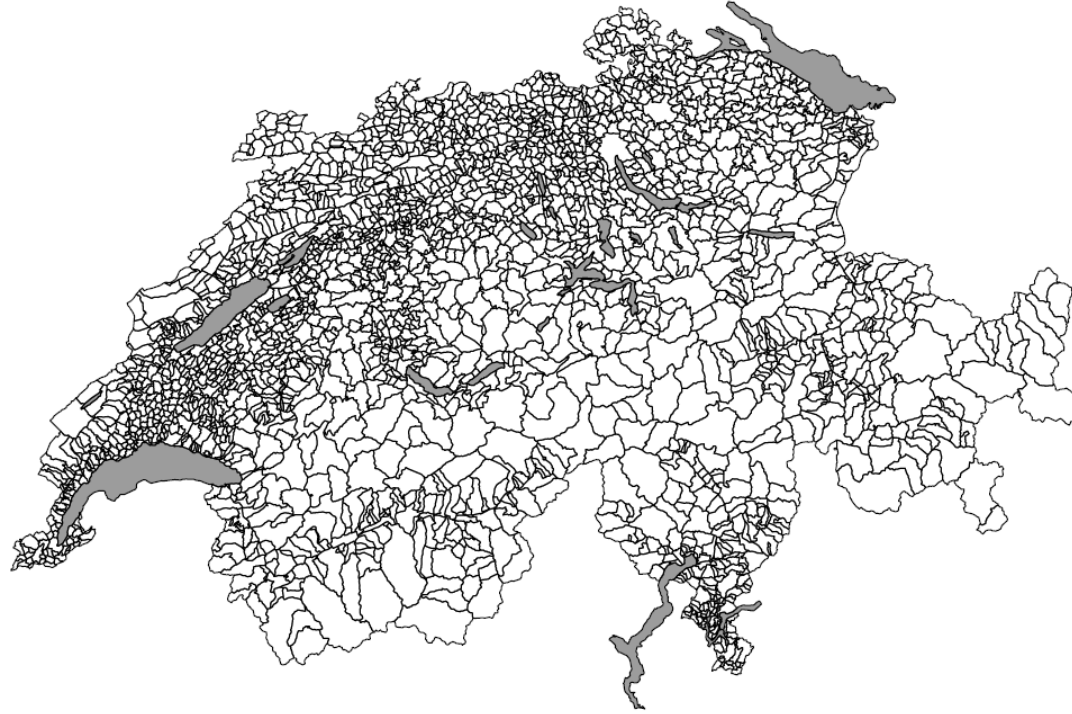
Micro-census mobility 2010 by Bundesamt für Statistik BFS and Bundesamt für Raumentwicklung ARE (2012).

- Socio-demographic variables: income, employment status, gender, education level
- Car availability
- GA (national-wide season-ticket) ownership
- Local season-ticket ownership

Accessibility data

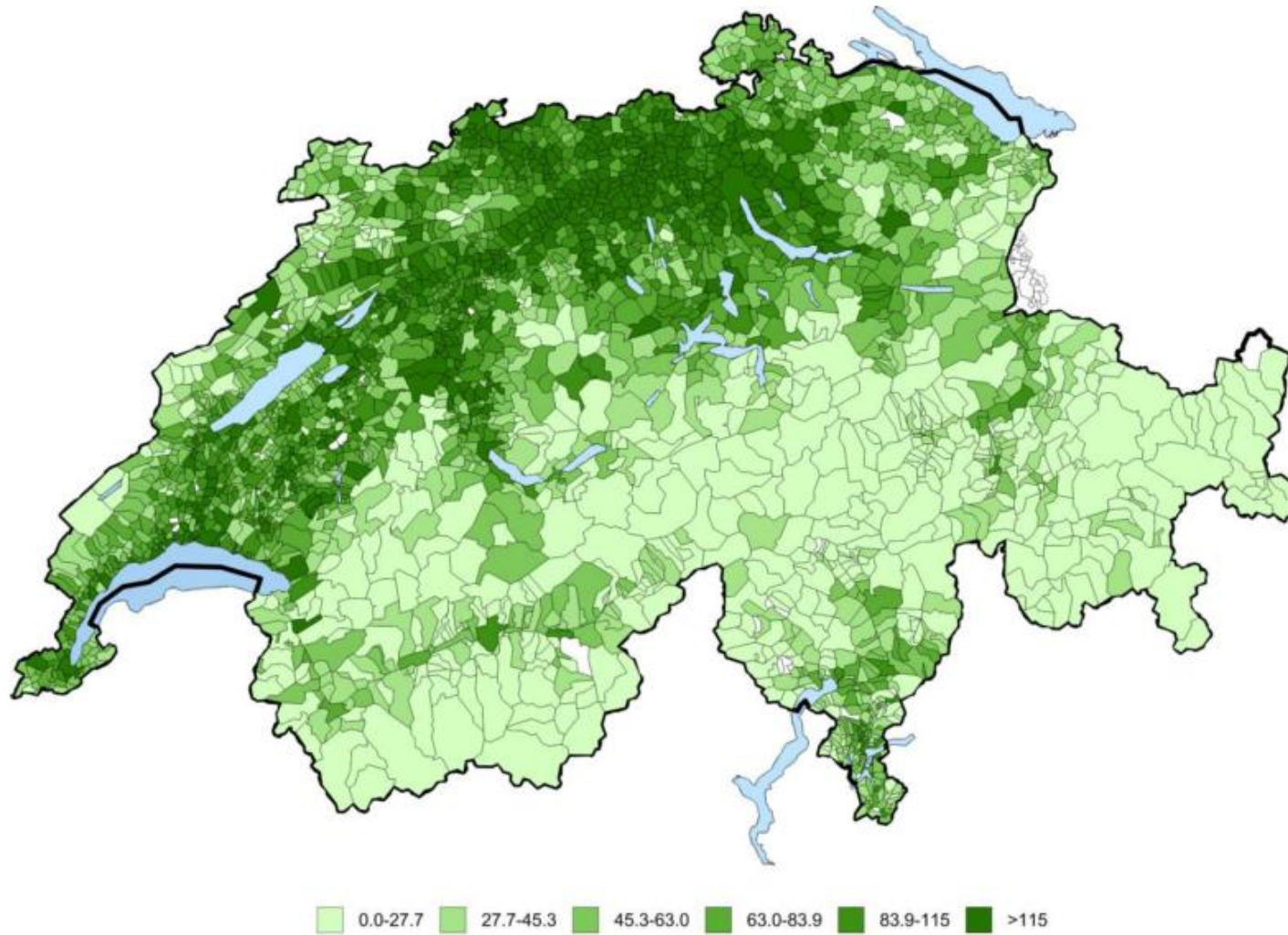
- Hansen's definition of accessibility at municipality level by Axhausen et al. (2015)
- Spatial typology (Bundesamt für Raumentwicklung ARE et al., 2011)
- Local access to public transport: Five level scale from none, D to A (best) provided by Bundesamt für Raumentwicklung ARE (2011).
- Household's distance to the center of the municipality
- Log of employment in resident municipality

Note to accessibility computation



$$Acc_{im} = \sum_{j \in \text{Zones}} opp_j \cdot e^{-\beta_m \cdot \text{Traveltime}_{ijm}}$$

Accessibility to employment by public transport



Axhausen et al. (2015)

Method: Bivariate probit

- Strong negative correlation between car and season-ticket ownership: Distinct modeling of ownership of car ownership and season-ticket ownership does not cover the choice
- Bivariate probit models capture this correlation directly (Green, 1996):

$$z_1 = \sum_k \beta_{k1} x_{k1} + \varepsilon_1$$

$$z_2 = \sum_k \beta_{k2} x_{k2} + \varepsilon_2$$

With bivariate and normal distributed errors:

$$[\varepsilon_1, \varepsilon_2] \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix} \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}\right)$$

- Extension to multivariate probit models is possible: In this case, GA and local season-ticket are exclusive choices with zero correlation imposing convergence difficulties to the log likelihood function

Procedure: Principal component analysis

Computed accessibility variables

- To population by private mode
- To population by public mode
- To employment by private mode
- To employment by public mode

But they show high degree of correlation: Carry out a principal component analysis to remove multicollinearity (Jolliffe, 2002):

- PC1: General levels of accessibility
- PC2: Better access by public transport
- PC3: Better access to employment
- PC4: omitted

Correlation of accessibility variables

	POP_PRV	POP_PUB	EMP_PRV	EMP_PUB
POP_PRV	1	0.741	0.983	0.754
POP_PUB	-	1	0.703	0.996
EMP_PRV	-	-	1	0.725
EMP_PUB	-	-	-	1

Correlation of accessibility variables and principal components

	PC1	PC2	PC3	PC4
POP_PRV	0.973	-0.217	-0.078	0.008
POP_PUB	0.944	0.327	-0.022	-0.028
EMP_PRV	0.966	-0.252	0.063	-0.007
EMP_PUB	0.948	0.315	0.027	0.026

Sample statistics

	Spatial typology															
	All				Urban core				Agglomeration				Countryside			
	Mean	St. Dev.	Min.	Max.	Mean	St. Dev.	Min.	Max.	Mean	St. Dev.	Min.	Max.	Mean	St. Dev.	Min.	Max.
Number of individuals	43406				13112				21285				8709			
GA ownership [%]	7.89				11.39				6.53				5.9			
Season-ticket ownership [%]	14.69				20.22				14.45				7.19			
Car availability [%]	79.61				70.42				83.25				84.52			
Monthly household income	6913	4117	1000	20000	6568	4003	1000	20000	7309	4282	1000	20000	6508	3779	1000	20000
Log of working places in municipality	8.29	2.02	0.26	12.62	10.43	1.36	7.04	12.62	7.55	1.26	2.2	10.24	6.4	1.27	0.26	9.12
Distance to municipality center in km	1.13	1.17	0	18.87	1.63	1.25	0.01	11.44	0.86	0.99	0	18.87	0.94	1.14	0	12.19
PC1	1.75	1.79	-11.61	5.81	2.52	1.72	-4.87	5.81	1.96	1.24	-5.48	4.9	-0.08	1.72	-11.61	3.35
PC2	0.01	0.68	-1.98	2.45	0.03	0.8	-1.98	1.7	-0.1	0.6	-1.91	1.49	0.22	0.59	-1.94	2.45
PC3	0.04	0.15	-0.49	0.51	0.04	0.18	-0.36	0.51	0.06	0.12	-0.3	0.44	-0.02	0.11	-0.49	0.51
Local access to public transport																
none [%]	23.36				5.74				21.74				58.03			
Level D [%]	26.55				15.01				32.46				31.54			
Level C [%]	20.89				22.06				24.76				8.9			
Level B [%]	16.35				26.75				15.2				1.26			
Level A [%]	12.86				30.43				5.84				0.29			
Gender: Male [%]	49.95				49.37				50.11				50.29			
Working [%]	67.56				66.3				66.87				71.16			
University education [%]	19.58				28.90				19.51				10.48			

Results: GA and car

Dependent variable	All		Urban core		Agglomeration		Countryside	
	GA	Car	GA	Car	GA	Car	GA	Car
Intercept	-3.623***	0.591***	-2.712***	-0.66*	-3.246***	0.778***	-4.302***	1.422***
log of monthly household income	0.195***	0.145***	0.168***	0.284***	0.172***	0.092***	0.303***	0.031
Gender								
Male (base)								
Female	-0.015	-0.274***	-0.036	-0.363***	-0.047	-0.195***	0.063	-0.295***
Employment status								
Not working (base)								
Working	0.035	-0.046	0.012	-0.156***	0.03	0.019	0.046	0.031
Female and working	-0.056	-0.013	0.042	0.028	-0.083	-0.08	-0.157	0.058
Attended university	0.308***	-0.186***	0.345***	-0.325***	0.276***	-0.097***	0.24***	-0.01
Distance to municipality center	-0.017	0.019**	-0.044**	0.051***	-0.002	0.03*	-0.015	0.013
Local acces to public transport								
None (base)								
Level D	0.007	-0.074***	-0.05	-0.084	0.079*	-0.107***	0.024	-0.127***
Level C	0.04	-0.09***	0.054	-0.135*	0.101*	-0.144***	0.037	-0.211***
Level B	0.087*	-0.161***	0.107	-0.208**	0.103*	-0.176***	0.301*	-0.338**
Level A	0.235***	-0.322***	0.203*	-0.284***	0.16*	-0.213***	-0.381	-0.494*
log of employment in municipality	0.045***	-0.093***	-0.033	-0.057*	0.014	-0.058***	0.005	-0.087***
PC1	0.008	-0.007	0.09***	-0.105***	-0.006	-0.004	0	0.004
PC2	0.132***	-0.084***	0.096***	-0.053**	0.169***	-0.129***	0.087**	-0.017
PC3	-0.121	-0.314***	-0.16	-0.203	0.165	-0.404***	-0.052	-0.273*
Correlation of error terms	-0.81***		-0.803***		-0.797***		-0.761***	
Number of observations	43406		13112		21285		8709	
Log likelihood	-32797		-10782		-13885		-7652	
Rho2	0.38		0.29		0.41		0.43	

Standard error in parentheses, *** p < 0.001, ** p < 0.01, * p < 0.5

Results: Season-ticket and car

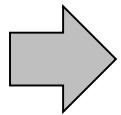
Dependent variable	All		Urban core		Agglomeration		Countryside	
	Car	Season-ticket	Car	Season-ticket	Car	Season-ticket	Car	Season-ticket
Intercept	-2.476***	0.609***	-2.738***	-0.633*	-2.61***	0.803***	-2.834***	1.41***
log of monthly household income	0.084***	0.143***	0.005	0.283***	0.109***	0.088***	0.138***	0.031
Gender								
Male (base)								
Female	0.084**	-0.275***	0.128*	-0.366***	0.067	-0.194***	0.038	-0.296***
Employment status								
Not working (base)								
Working	-0.025	-0.041	-0.016	-0.153***	-0.011	0.029	-0.041	0.03
Female and working	0.195***	-0.013	0.147*	0.029	0.226***	-0.081	0.225**	0.059
Attended university	0.042*	-0.188***	-0.049	-0.325***	0.095***	-0.096***	0.16**	-0.009
Distance to municipality center	0.024***	0.02**	0.052***	0.051***	-0.014	0.03*	-0.036	0.012
Local access to public transport								
None (base)								
Level D	0.161***	-0.074***	0.047	-0.091	0.172***	-0.107***	0.118**	-0.128***
Level C	0.226***	-0.089***	0.133	-0.143*	0.185***	-0.144***	0.326***	-0.209***
Level B	0.348***	-0.161***	0.224**	-0.219**	0.321***	-0.174***	-0.094	-0.335**
Level A	0.424***	-0.323***	0.278***	-0.294***	0.451***	-0.214***	0.916***	-0.489*
log of employment in municipality	0.016*	-0.093***	0.119***	-0.058*	0.005	-0.058***	0.003	-0.086***
PC1	0.095***	-0.007	0.073***	-0.105***	0.115***	-0.004	0.028*	0.004
PC2	0.008	-0.084***	0.014	-0.054**	0.051**	-0.128***	0.005	-0.02
PC3	0.666***	-0.313***	0.302*	-0.208	0.542***	-0.404***	0.209	-0.272*
Correlation of error terms	-0.645***		-0.537***		-0.727***		-0.716***	
Number of observations	43406		13112		21285		8709	
Log likelihood	-38013		-12421		-17245		-7815	
Rho2	0.3		0.2		0.29		0.42	

Standard error in parentheses, *** p < 0.001, ** p < 0.01, * p < 0.5

Computation of elasticities

What is the effect of travel time changes / accessibility changes on the mobility tool choice?

Problem: Elasticities cannot be directly be derived as there are no β s for the four accessibility variables



Use factor loading matrix to transform incremental changes from the sample mean of each of the four accessibility variables and simulate the effect on the choice probability

Elasticities: Simulation results

Choice:		Car and GA				Car and local season-ticket			
	Accessibility to	population by		employment by		population by		employment by	
		PRV	PUB	PRV	PUB	PRV	PUB	PRV	PUB
All	None	-0.235	-0.031	0.182	0.096	-0.089	0.015	-0.007	0.043
	Only Car	0.087	-0.004	-0.050	-0.046	0.163	0.017	-0.144	-0.078
	Only Season-ticket	-0.091	0.103	-0.065	0.117	-0.529	-0.073	0.530	0.251
	Both	0.258	0.161	-0.348	-0.018	-0.360	-0.081	0.471	0.170
Urban core	None	-0.167	-0.010	0.217	0.109	-0.002	0.055	0.035	0.067
	Only Car	0.049	-0.055	-0.095	-0.099	0.153	-0.022	-0.206	-0.135
	Only Season-ticket	0.131	0.217	-0.059	0.156	-0.276	0.014	0.357	0.213
	Both	0.427	0.229	-0.451	-0.046	-0.163	-0.064	0.169	0.041
Agglo- meration	None	-0.423	-0.018	0.283	0.176	-0.357	0.002	0.148	0.149
	Only Car	0.094	-0.005	-0.047	-0.046	0.126	0.003	-0.109	-0.062
	Only Season-ticket	-0.566	0.063	0.229	0.294	-0.689	-0.022	0.639	0.349
	Both	-0.142	0.092	-0.073	0.126	-0.358	-0.025	0.506	0.211
Country- side	None	0.027	-0.009	-0.034	0.009	0.024	-0.006	-0.027	0.009
	Only Car	-0.003	0.000	0.003	-0.002	-0.004	0.001	0.005	-0.002
	Only Season-ticket	0.015	0.004	-0.004	0.010	0.034	-0.008	-0.045	0.016
	Both	-0.012	0.015	0.033	0.002	0.012	-0.002	-0.022	0.008

Summary of findings

- Results are intuitive and supporting the hypothesis. Better access by public transport increases the probability of opting for the season-ticket, better access by private transport car availability. Better access to employment favors public transport.
- Choices in the countryside exhibit only marginal influence of accessibility
- GA tends to be more substitute of a car than a season-ticket
- Local access to public transport shows significant influence on local season-ticket but not on the GA:
Emphasizing the long-commuting characteristic of the GA

Problems

- Validity of linear transformation and simulation of elasticities?
- Possibility to incorporate the three choices within a multivariate probit?

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