

# Pigovian Transport Pricing in Practice

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**zhaw**

# Introduction

Market failure in transportation due to **external costs**:

- Emissions (CO<sub>2</sub>, air pollution, noise)
- Congestion
- Accidents
- Physical activity
- (Road damage/upkeep: largely internalized)

So far: Second-best and usually single-mode policies that only partially fix this multi-dimensional problem

# This paper: “Pigovian” transport pricing

- 1 Compute social marginal damage of each trip from most relevant externalities, for all modes
- 2 Implement the monetized value as a tax in a randomized controlled trial with smartphone-based tracking
- 3 Identify causal effect of pricing and information on transport choices
- 4 Investigate mechanisms and treatment effect heterogeneity

# Literature

→ Before-vs-after experiments:

Nielsen (2004), Ben-Elia and Ettema (2011), Maerivoet et al. (2012), Pluntke and Prabhakar (2013), Martin and Thornton (2017)

→ Actual policy interventions:

Congestion charges e.g. in London (Leape, 2006), Sweden (Börjesson and Kristoffersson, 2018) and Norway (Isaksen and Johansen, 2020)

→ RCTs:




Kreindler (2020), Kristal and Whillans (2020), Rosenfield et al. (2020)




# External costs of transport

- Rely on values values published by Swiss Federal Office of Spatial Development
- Focus on
  - air pollution (PM10, NOx) and noise
  - climate (CO2)
  - accidents
  - health benefits from active transport
  - congestion
- PT and active transport: Constant per-km values
  - PT: 10 cents/km for crowded links during peak hours
- Cars: Individualized computation of all external costs within Swiss scenario of MATSim (Horni, Nagel and Axhausen, 2016)

# Messages: Control group





Report | Week 5  
26.10.2019 - 01.11.2019









Dear Mr John Doe

Thank you for participating in the MOBIS study. This week was the 5th week of the study.

Your participation this week: 7 active days and 0 inactive days

Your use of different travel modes and their external costs are displayed below.

### Distance by transport mode

 239 km	 0 km	 23 km **	 0 km	 7 km
				

▲ Increase/decrease in travel distance since last week  
\*\* Includes all local public transport: Bus, Tram, Metro & S-Bahn

# Information & pricing groups: Halftime e-mail



## MOBIS - Important information about the second phase of the study

Dear Mr. Doe

Thank you for participating in the first four weeks of the MOBIS study! **Please read the following message carefully**, as we are introducing a few important changes to the study going forward.

This is exciting as you have the opportunity to earn more than the original CHF 100. How? By reducing the external costs of your travel.

### What are external costs?

We all pay the private costs of our travel - tickets, petrol, time, etc. However, travel also has impacts on other members of society. These are called the *external costs* of mobility. They include the impacts of congestion, accidents, environmental pollution and traffic noise.

### How does this second phase work?

For the second phase of the study, which will last four weeks, we will provide you with a mobility budget of **CHF 100.00**. This amount has been calculated on the basis of your external costs in the first phase.

The external costs of your mobility in this second phase will be deducted from this budget, with **any remaining positive amount paid to you at the end of the study**. You can reduce your external costs compared to the first four weeks by the methods suggested below.

If you participate until the end, you will receive the initially promised CHF 100 reward, in addition to your remaining mobility budget.

We will provide you with weekly updates of your balance via email. Real-time updates are unfortunately not possible at the moment.

For periods during which we cannot track you (e.g. when you are abroad or tracking is deactivated), your budget will be reduced proportionally.











# Information & pricing groups: Feedback

## Your external costs for the last week



\*Includes the public transport [peak hour surcharge](#)

	Profit	Costs	Total
			CHF 25.52
			CHF 0.00
			CHF 0.75
			CHF 0.00
			CHF -0.72

# Pricing group

Remaining Budget on 01.11

CHF 74.46

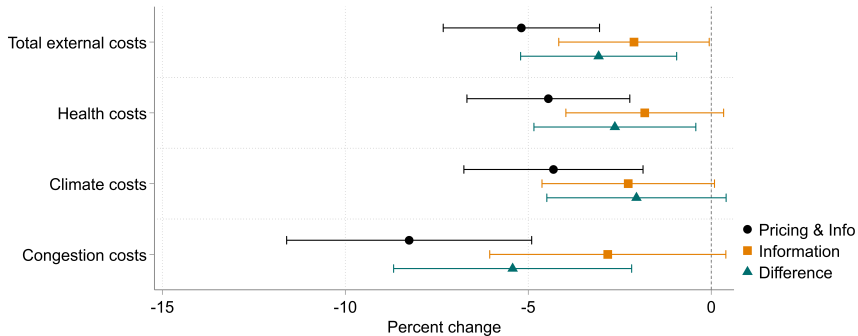
This is an estimate based on your most recent available data.  
CHF 3.57 was deducted from your budget per inactive day and  
per day abroad.

# Summary statistics

Dimension	Outcome	Pre-treatment			Post-treatment		
		Control	Info	Pricing	Control	Info	Pricing
Ext. costs (CHF)	Total	4.51 (5.66)	4.60 (5.63)	4.71 (5.80)	4.24 (5.39)	4.27 (5.53)	4.25 (5.41)
	Congestion	1.04 (1.58)	1.07 (1.58)	1.14 (1.69)	0.85 (1.44)	0.87 (1.53)	0.90 (1.52)
	Climate	0.88 (1.29)	0.88 (1.29)	0.90 (1.30)	0.85 (1.23)	0.84 (1.28)	0.83 (1.22)
	Health	2.59 (3.53)	2.64 (3.53)	2.67 (3.60)	2.53 (3.47)	2.56 (3.56)	2.52 (3.46)
	Private cost (CHF)	26.06 (33.59)	26.69 (33.92)	26.87 (34.49)	25.71 (33.39)	25.96 (34.02)	25.56 (33.21)
Tracking	Days	23.14 (3.73)	23.30 (3.58)	23.17 (3.87)	22.99 (3.93)	23.00 (4.04)	22.81 (4.19)
	Trips	4.71 (3.02)	4.74 (3.00)	4.76 (2.96)	4.53 (2.81)	4.49 (2.79)	4.55 (2.83)
	Distance (km)	46.96 (55.23)	48.02 (54.59)	49.47 (57.31)	45.55 (54.17)	47.25 (55.88)	47.41 (55.01)
	Duration (min)	92.77 (84.71)	93.63 (80.16)	94.42 (82.87)	88.57 (78.85)	90.76 (82.11)	91.38 (82.87)

*Notes:* Average values per participant and day (except for tracking days) during the experiment (SD in parentheses).

# Average Treatment Effects



(Proportional effect of treatments on external costs)

# Elasticities

Proportional effect: -5.2%

Price increase due to treatment: 16.4%

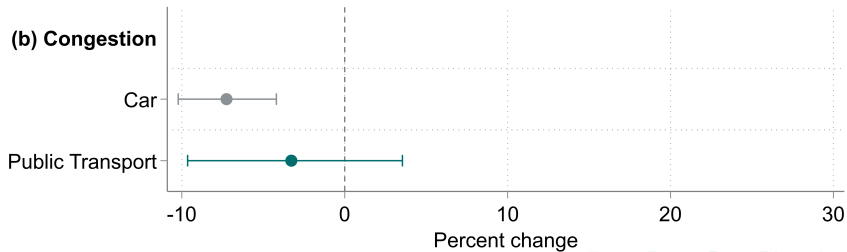
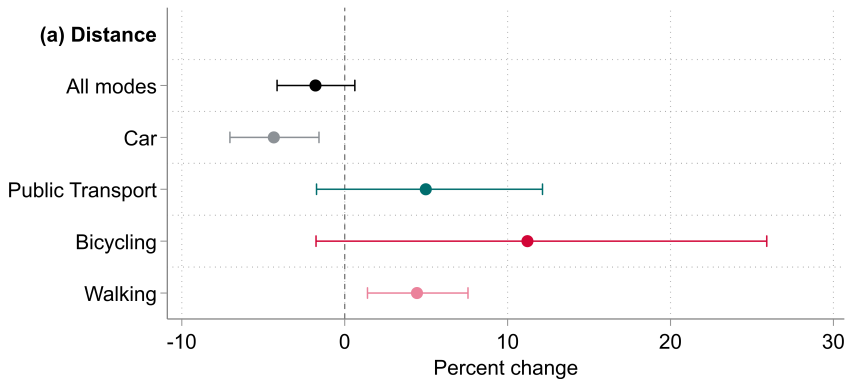
⇒ Elasticity: **-0.32**

(Elasticity of external costs with respect to a total transport price increase due to Pigovian Pricing)

# Effect heterogeneity

- Proportional effect relatively homogeneous
- Variation in absolute effects
  - Significant interaction terms: language, age, urbanity, car ownership
  - Effect from pricing driven by those that correctly identified definition of external costs after experiment
- Net tax highest for men and high-income households
- Altruists respond stronger to information treatment

# Mechanisms



# Robustness tests

- Observation effect
  - Recorded external costs decreased over course of study, even when controlling for calendar date
  - But: No differential trend across groups ◀ Trends
  - Important to have a control group
- Potential cheating by participants
  - Participants of pricing group not more likely to adjust modes ◀ Corrections
  - Results do not change when excluding all person-day observations that include at least one correction
- Potential nonrandom attrition
  - Attrition rates low and similar across groups
  - Similar results using weeks 5-6 vs. weeks 7-8 ◀ Subsamples
- No change when removing days with zero recorded travel



# External validity

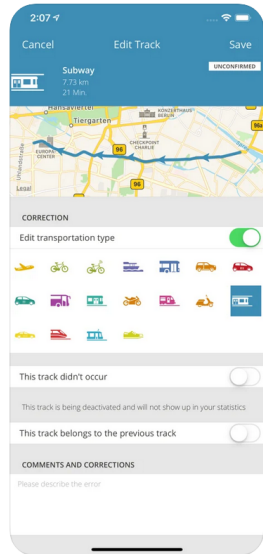
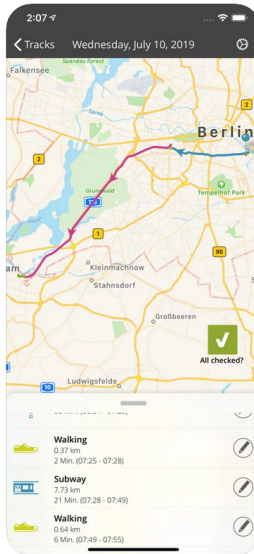
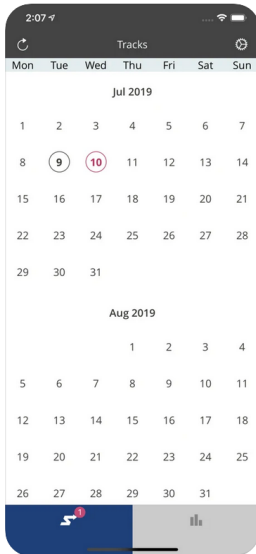
- Self-selection
  - sample quite similar to overall population according to observable characteristics
  - slightly younger, over-representation of drivers
  - “willingness to track”
- Long-run effects likely larger
  - additional margins of response
  - salience
- Deducting money from budget rather than taxing
  - loss aversion?
  - “real” vs. “house” money (Thaler, 1990)
- Swiss urban areas setting
  - mode shift to PT only where PT is available
  - shifts in departure time and routes can happen anywhere
  - larger response in rural municipalities

# Discussion

- Pigovian transport pricing works, in theory and practice
  - Short-term elasticity of around -0.32
  - Payment of CHF 4.22 per person-day (1,500 CHF/year)
- Results largely consistent with literature, but not directly comparable due to inclusion of all external costs and all modes
- Proportional effect homogenous (absolute effect is not)
- Implementation has to be simpler and focus on main external costs
- Regressive, but (probably) not more so than VAT
- Some support for transport pricing in final survey



# Tracking App: Interface

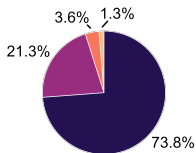


# External costs per person-km

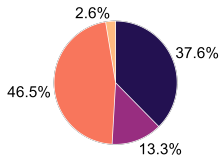
Mode	Congestion	CO <sub>2</sub>	Health	Total	
				w/o Congestion	incl. Congestion
Car	0.0332	0.0258	0.0781	0.1039	0.1371
Train	0 / 0.1	0.00007	0.0141	0.0141	0.1141
Tram	0 / 0.1		0.0141	0.0141	0.1141
Bus	0 / 0.1	0.0144	0.0710	0.0854	0.1854
Bicycle			0.07	0.07	
Walk			-0.11	-0.11	

# Distance, trips & external costs by mode

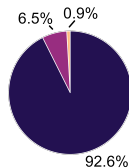
(a) Distance



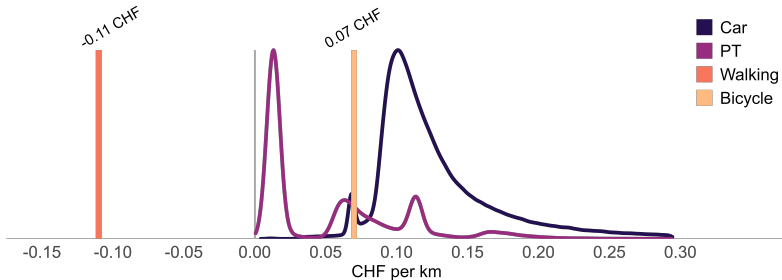
(b) Trips



(c) External costs



(d) External costs per kilometer



# Estimation: Difference-in-differences

$$Y_{its} = c_0 + \alpha^P \cdot DiD_{its}^P + \alpha^I \cdot DiD_{its}^I + \mu_i + \mu_t + \mu_s + \epsilon_{its}$$

$y_{its}$  : Outcome for person  $i$  on calendar day  $t$  on study day  $s$

$DiD_{its}^X$  : Treatment indicator for  $X = (I, P)$  ( $\equiv D_i^X \cdot D_{ts}^X$ )

$\mu_i, \mu_t, \mu_s$  : Person, day of calendar and day of study FE

$\epsilon_{its}$  : Error term (correlation within person  $i$  allowed)

$\alpha^P$  : ATE for Information & Pricing treatment

$\alpha^I$  : ATE for Information treatment

$\alpha^P - \alpha^I$  : ATE for adding price to information

# Average Treatment Effects

	(1)	(2)	(3)	(4)	(5)	(6)
Pricing	-0.217** (0.074)	-0.229** (0.066)	-0.225** (0.074)	-0.489** (0.054)		
Information	-0.091 (0.071)	-0.101 (0.062)	-0.098 (0.072)	-0.362** (0.051)		
Post					-0.314** (0.108)	-0.489** (0.054)
Constant	4.264 (0.020)	4.268 (0.017)	4.267 (0.02)	4.352 (0.012)	4.402 (0.052)	4.487 (0.026)
Prop. Effects	-0.0538	-0.0568	-0.0559	-0.1215	-0.0701	-0.1092
Elasticity	-0.328	-0.346	-0.341	-0.741	-0.401	-0.625
Person FE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Calendar FE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Study day FE	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Adj. R <sup>2</sup>	0.221	0.221	0.218	0.218	0.219	0.215
Cluster	3,656	3,656	3,656	3,656	1,193	1,193
N	168,836	168,836	168,837	168,837	54,821	54,824

Notes: \*\*:  $p < 0.01$ , \*:  $p < 0.05$ , †:  $p < 0.1$ . Standard errors in parentheses and clustered at participant level. "Post"=1 during the treatment period (study days 29-56) and zero otherwise.



Table 1: Elasticities for subsamples

	Treatment effect (%)			Price increase (%)			Elasticity (%)			p	N
	Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound		
Age>54	-6.28	-14.02	1.45	16.22	15.83	16.62	-38.73	-86.56	9.10	0.112	32,221
30≤Age≤54	-2.92	-7.22	1.39	16.61	16.37	16.86	-17.55	-43.50	8.39	0.185	89,863
Age<30	-9.51	-16.32	-2.70	16.39	16.01	16.77	-58.02	-99.53	-16.51	0.006	42,822
German sp.	-7.34	-11.33	-3.35	16.31	16.10	16.52	-44.99	-69.46	-20.52	0.000	110,146
French sp.	1.31	-5.41	8.04	16.85	16.46	17.24	7.79	-32.08	47.67	0.702	42,666
English sp.	-5.38	-17.63	6.88	17.22	16.34	18.10	-31.23	-102.54	40.08	0.391	12,093
Urban	-3.53	-7.85	0.80	16.80	16.55	17.05	-21.00	-46.79	4.79	0.110	106,009
Non-urban	-5.98	-11.96	0.01	16.14	15.81	16.47	-37.02	-74.18	0.14	0.051	45,464
Rural	-12.42	-22.40	-2.44	15.71	15.19	16.23	-79.05	-142.98	-15.13	0.015	13,426
Car owner	-5.06	-8.31	-1.80	16.46	16.27	16.66	-30.71	-50.49	-10.93	0.002	144,680
No car owner	-6.34	-19.12	6.44	16.68	16.04	17.33	-37.99	-114.61	38.62	0.331	20,231
Incorrect EC	-0.35	-3.97	3.26	16.48	16.29	16.67	-2.15	-24.08	19.79	0.848	117,329
Correct EC	-10.30	-14.73	-5.87	16.48	16.29	16.67	-62.51	-89.43	-35.58	<0.001	105,892

Notes: \*\*:  $p < 0.01$ , \*:  $p < 0.05$ , †:  $p < 0.1$ . Standard errors in parentheses and clustered at participant level. The dummy variable “post” takes the value of one during the treatment period (study days 29-56), and zero otherwise.

# Pre-treatment trends in external costs [◀ Back](#)

	All Travel	All Travel	Car	PT	Bicycle	Walking
Info	0.0883 (0.1169)	-0.0127 (0.1574)	-0.0382 (0.1594)	0.0427 (0.0281)	-0.0039 (0.0078)	-0.0133 (0.0074)
Pricing	0.1669 (0.1188)	0.0254 (0.1584)	-0.0241 (0.160)	0.0604* (0.0294)	0.0023 (0.0091)	-0.0132' (0.0072)
Study Day	-0.0154** (0.0039)	-0.0208** (0.0054)	-0.0207** (0.0054)	0.0007 (0.001)	-0.0001 (0.0003)	-0.0006* (0.0003)
Pricing x Study Day		0.0095 (0.0064)	0.0089 (0.0065)	0.0003 (0.001)	-0.0002 (0.0003)	0.0004 (0.0003)
Info x Study Day		0.0067 (0.0064)	0.0072 (0.0065)	-0.001 (0.001)	0.0000391 (0.0003)	0.0005 (0.0003)
Constant	4.5387 (0.1025)	4.6188** (0.1203)	4.5097** (0.1213)	0.2555** (0.023)	0.0497** (0.0061)	-0.196** (0.0054)
Adj. R <sup>2</sup>	0.0054	0.0054	0.0051	0.0089	0.0063	0.0112
N	86,782	86,782	86,782	86,782	86,782	86,782

Notes: \*\*:  $p < 0.01$ , \*:  $p < 0.05$ , ' :  $p < 0.1$ . The dependent variable is the external cost of transport (in CHF), aggregated to the person-day level. Standard

	Corrections	Corrections	Prob. (Corr.)	Prob. (Corr.)
Pricing	1.024 (0.066)	1.009 (0.065)	0.002 (0.006)	0.0003 (0.007)
Information	0.981 (0.063)	0.976 (0.063)	0.000 (0.007)	-0.001 (0.007)
Controls	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
N	74,899	72,759	74,858	72,718

*Notes:* \*\*:  $p < 0.01$ , \*:  $p < 0.05$ , ' :  $p < 0.1$ . Standard errors in parentheses and clustered at participant level. The dependent variable in the first two columns is the number of mode corrections per day. The coefficients are proportional effects, estimated using a ppml model. Columns 3-4 display the marginal effects from logit regressions. All regressions control for calendar and study day FE.

# Subsample analysis

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	Baseline	w/o corrections	w/o weeks 7-8	w/o weeks 5-6	w/o zeroes
Pricing	-0.217** (0.075)	-0.238** (0.080)	-0.232** (0.085)	-0.236** (0.089)	-0.216** (0.074)
Information	-0.906 (0.072)	-0.075 (0.078)	-0.101 (0.083)	-0.079 (0.087)	-0.091 (0.071)
Constant	4.260 (0.020)	4.711 (0.019)	4.325 (0.015)	4.294 (0.016)	4.655 (0.020)
Prop. effect	-0.054	-0.053	-0.057	-0.059	-0.049
Elasticity	-0.328	-0.324	-0.343	-0.366	-0.299
Clusters	3,656	3,656	3,656	3,656	3,656
Adj.R <sup>2</sup>	0.222	0.238	0.225	0.222	0.238
N	168,836	139,699	127,096	128,521	154,522

*Notes:* \*\*:  $p < 0.01$ , \*:  $p < 0.05$ , ' :  $p < 0.1$ . Standard errors in parentheses and clustered at participant level. All regressions include fixed effects for person, day of study and day of calendar. The proportional effect and the elasticity are computed using the averages of the control group subject to the appropriate restrictions.

# Sample demographics (1/2)

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Variable	Level	MOBIS Intro	Mobis Tracking			MTMC
			Control	Info	Pricing	
Age	[18, 25]	20.1	18.2	20.1	19.8	14.3
	(25, 35]	19.4	18.1	18.7	16.8	21.4
	(35, 45]	19.9	22.2	20.9	24.5	22.6
	(45, 55]	21.6	22.9	24.0	22.7	23.7
	(55, 65]	19.0	18.5	16.2	16.2	17.9
Education	Mandatory	9.2	8.0	5.1	6.8	13.8
	Secondary	43.3	47.4	49.5	48.5	47.5
	Higher	47.5	44.6	45.4	44.8	38.7
Employment	Employed	68.7	73.6	71.9	71.0	68.8
	Self-employed	7.3	6.3	5.2	7.4	8.8
	Apprentice	1.9	1.9	1.6	1.7	2.2
	Unemployed	4.4	3.4	4.0	4.6	3.9
	Student	9.3	7.5	8.7	7.7	3.0
	Retired	2.5	2.6	2.1	2.3	3.6
	Other	5.9	4.8	6.5	5.3	9.7
Gender	Male	48.9	50.0	49.7	49.5	49.4
	Female	51.1	50.0	50.3	50.5	50.6
Household size	1	15.5	11.4	11.6	12.1	18.3
	2	31.7	30.2	30.7	28.6	32.0
	3	20.5	22.8	21.7	20.1	19.9
	4	23.6	25.2	27.9	29.9	20.7
	5 or more	8.6	10.4	8.1	9.3	9.1
Income	4,000 CHF or less	12.2	6.7	8.2	7.3	8.8
	4,001 - 8,000 CHF	29.4	30.7	30.2	27.2	31.4
	8,001 - 12,000 CHF	24.5	28.1	29.7	29.9	24.6
	12,001 - 16,000 CHF	12.1	15.8	13.7	14.4	11.7
	More than 16,000 CHF	8.0	9.6	9.3	10.7	8.4
	Prefer not to say	13.8	9.2	8.9	10.6	5.8
	Don't know					9.2
N		20,783	1,229	1,233	1,182	21,399

# Sample demographics (2/2)

Variable	Level	MOBIS Intro	Mobis Tracking			MTMC
			Control	Info	Pricing	
Language	German	62.7	66.4	65.0	66.5	69.5
	French	28.6	26.0	26.8	26.3	26.5
	Italian					4.0
	English	8.7	7.6	8.1	7.2	
Nationality	Switzerland	78.1	81.3	80.3	82.1	69.5
	Other	21.9	18.7	19.7	17.9	30.5
Access to car	Yes	61.0	87.0	87.8	88.2	69.7
	Sometimes	15.5	11.9	10.6	10.9	22.7
	No	23.5	1.1	1.5	0.9	7.5
Full PT subscription	Yes	37.2	21.7	24.9	25.2	34.5
	No	62.8	78.3	75.1	74.8	65.5
Half fare PT subscription	Yes	47.6	49.0	48.8	48.1	37.6
	No	52.4	51.0	51.2	51.9	62.4
No PT subscription	Yes	26.0	34.0	32.8	34.2	37.9
	No	74.0	66.0	67.2	65.8	62.1
Access to bicycle	Yes	68.5	72.6	71.6	69.5	70.1
	Sometimes	4.1	4.4	5.5	3.8	8.8
	No	27.4	23.0	22.9	26.6	21.1
N		20,783	1,229	1,233	1,182	21,399

*Notes:* Descriptive statistics shown for the MOBIS introduction survey, the MOBIS tracking, and the weighted Swiss Mobility and Transport Microcensus 2015 (MTMC) samples. All samples restricted to 18 to 65 year olds, with the MTMC sample additionally restricted to the Federal Statistical Office's Commune Numbers present in the MOBIS introduction survey sample.

# Acceptance

