Non-work/school activity participation in a flexible work future: A pre/post-pandemic comparative study
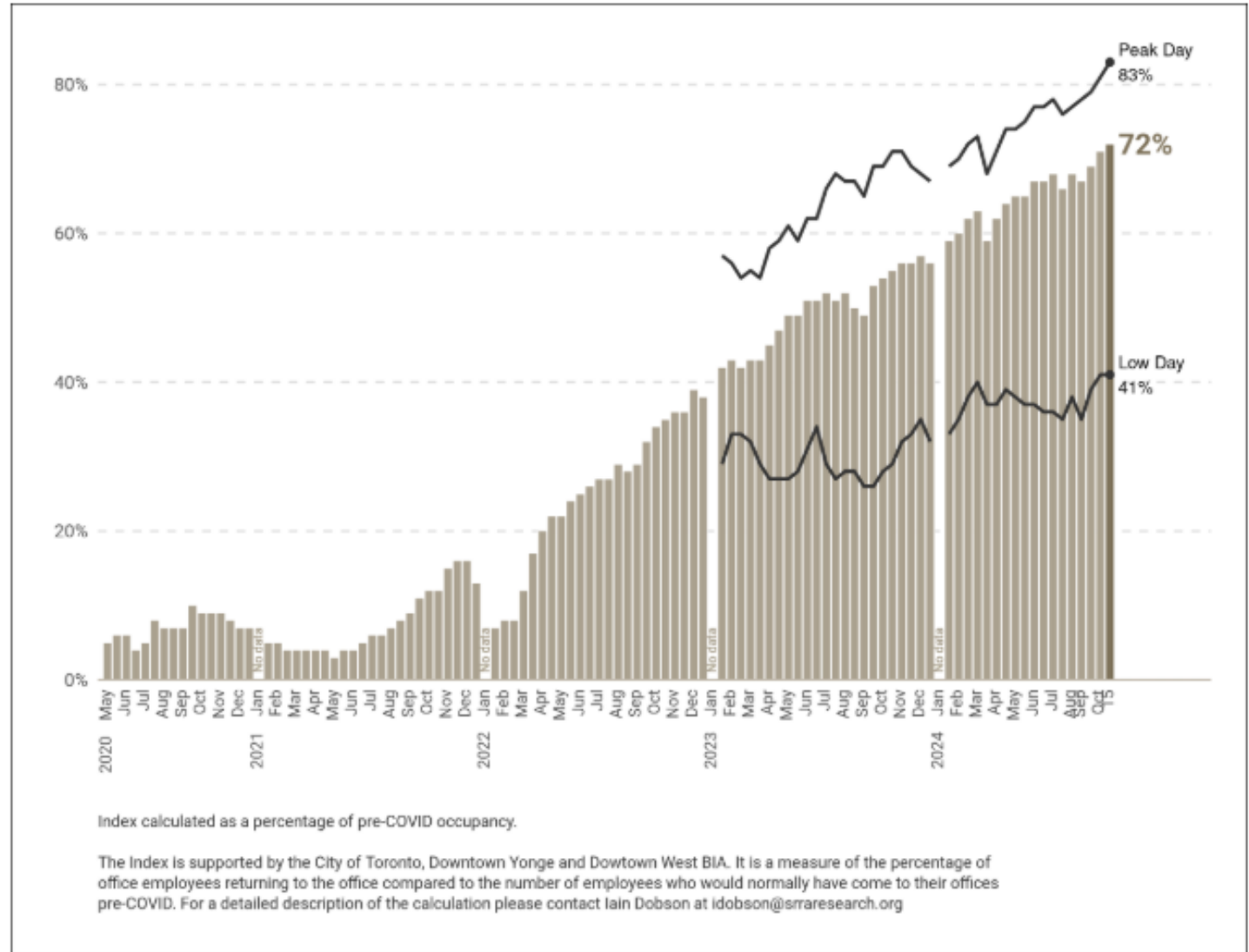
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City of Toronto Downtown Occupancy Index

- A hybrid work environment is here to stay.

- This raises many challenges for activity-based travel demand modelling.

- In this study we look at the relationship of NWS activity participation with work "modality".

Index calculated as a percentage of pre-COVID occupancy.

The Index is supported by the City of Toronto, Downtown Yonge and Dowtown West BIA. It is a measure of the percentage of office employees returning to the office compared to the number of employees who would normally have come to their offices pre-COVID. For a detailed description of the calculation please contact Iain Dobson at idobson@srraresearch.org

Worker "Modality"

- Onsite worker: Has an out-of-home workplace and must work onsite.

- Remote worker: Does not have an out-of-home workplace and always works at home.

- Hybrid worker: Has an out-of-home workplace; sometimes works onsite, sometimes works from home (WfH).

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Non-work/school activities investigated

- Shopping.
- Leisure/personal business.

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Data

- Toronto Tomorrow Survey (TTS) Fall, 2016
  - 5% sample
  - Primarily web-based
  - One weekday
- Toronto Household Activity-Travel Survey (THATS) Spring, 2023
  - Small sample
  - Smartphone app + web
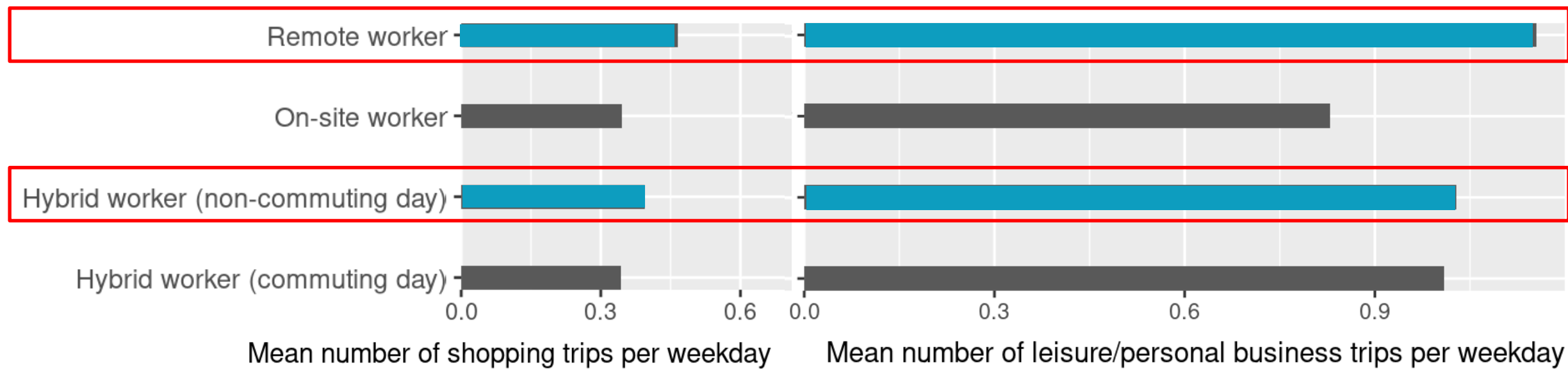 - Week-long (7-day)

Attribute	Category	TTS 2016	THATS 2023
Gender	Female	0.4772	0.4716
	Male	0.5228	0.5157
	Others	N/A	0.0128
Age	17 or less	0.0144	0.0063
	18 to 24	0.0680	0.0314
	25 to 34	0.1823	0.2954
	35 to 49	0.3442	0.4460
	50 to 64	0.3344	0.1930
	65 or more	0.0568	0.0278
Work modality	On-site worker	0.9411	0.3323
	Remote worker	0.0589	0.1943
	Hybrid worker	N/A	0.4734
Work status	Full time	0.8330	0.8935
	Part time	0.1670	0.1065
Sample size (# of trip-days)		172244	10975

*All numbers are proportions except for sample sizes.

Hypothesis (1): Activity participation of **hybrid workers on commuting days** is similar to that of **on-site workers**.
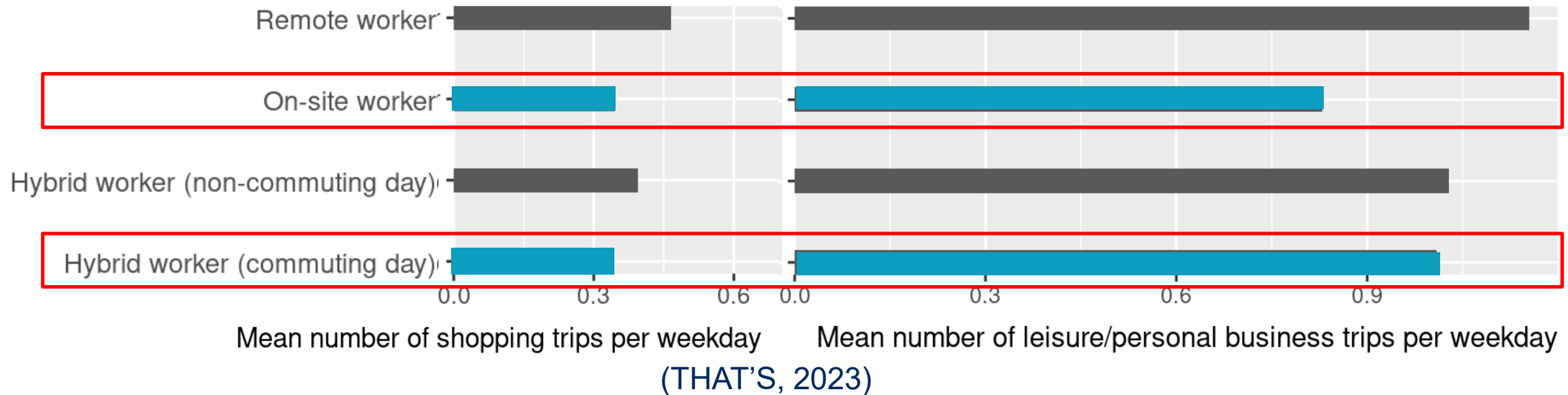
(THAT'S, 2023)

Hypothesis (2): Activity participation of **hybrid workers on non-commuting days** is similar to that of **remote workers**.

(THAT'S, 2023)
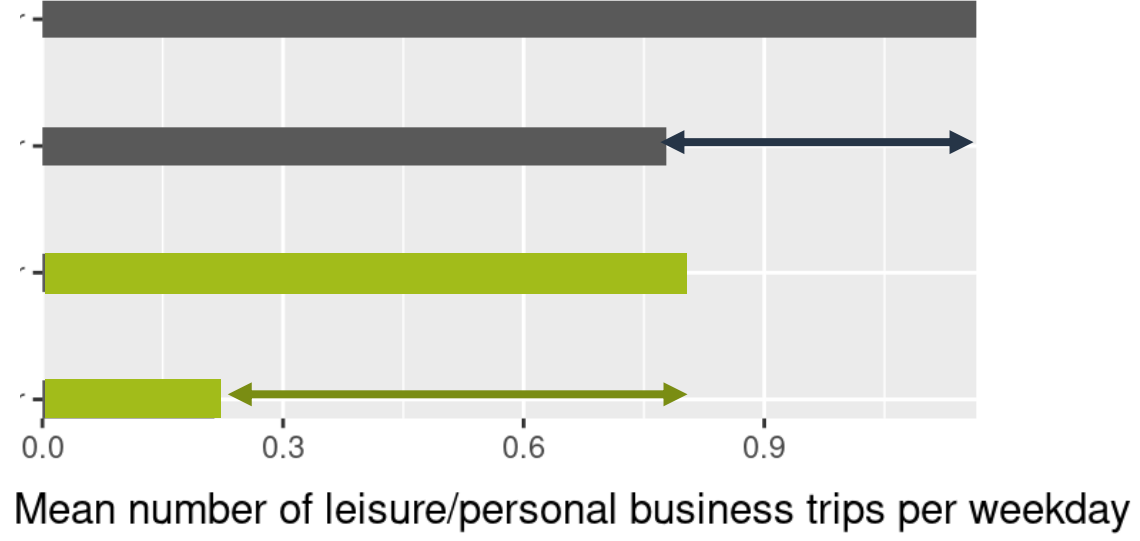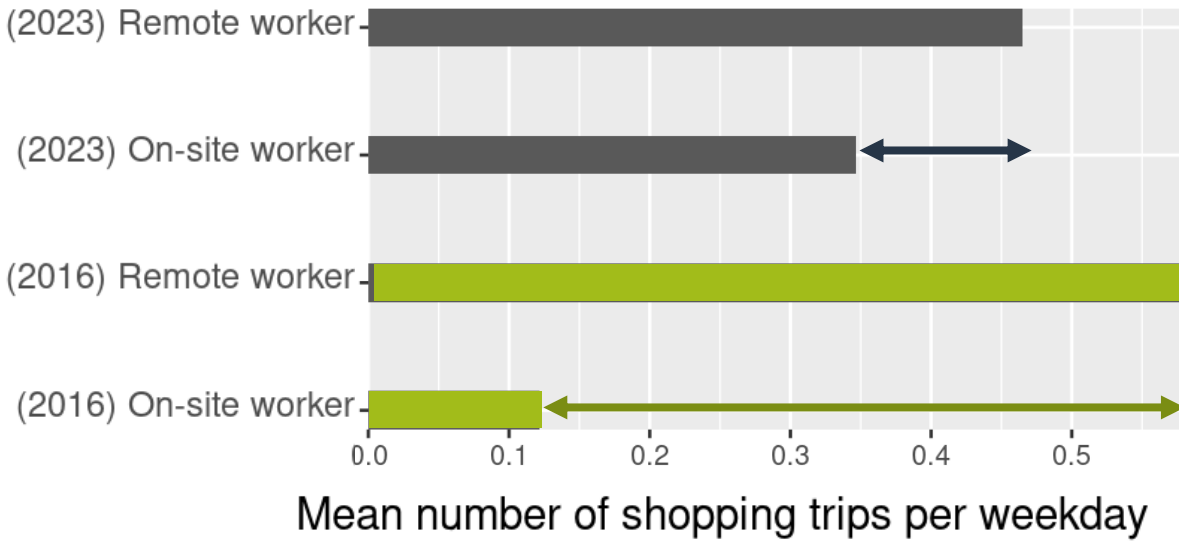
Hypothesis (3): **Post-pandemic** activity participation behaviour differs in nature from **pre-pandemic** behaviour.

Mean number of shopping trips per weekday

Mean number of leisure/personal business trips per weekday

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Hypothesis (3): **Post-pandemic** activity participation behaviour differs in nature from **pre-pandemic** behaviour.
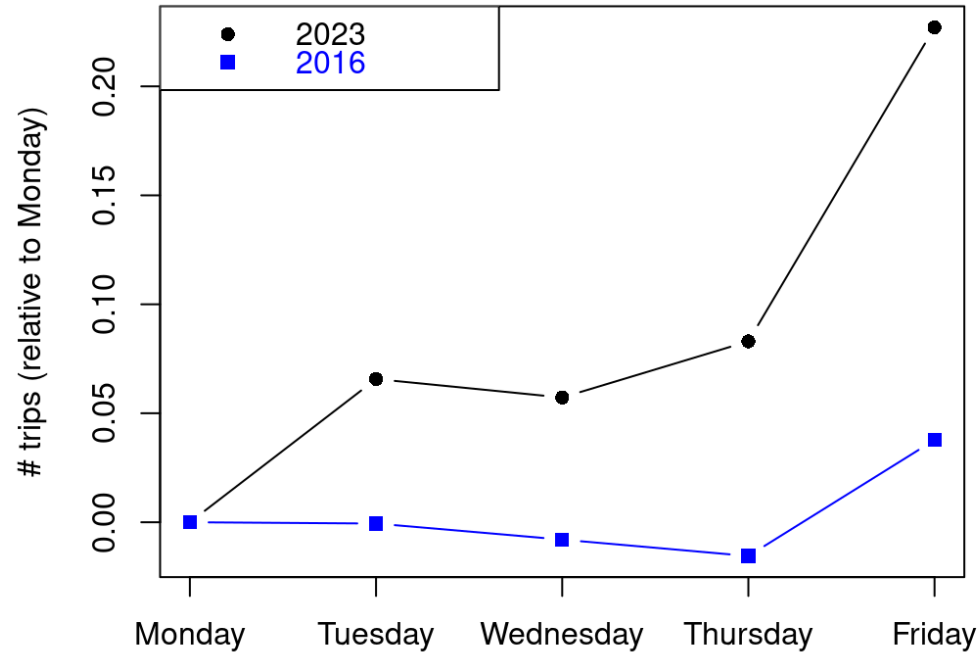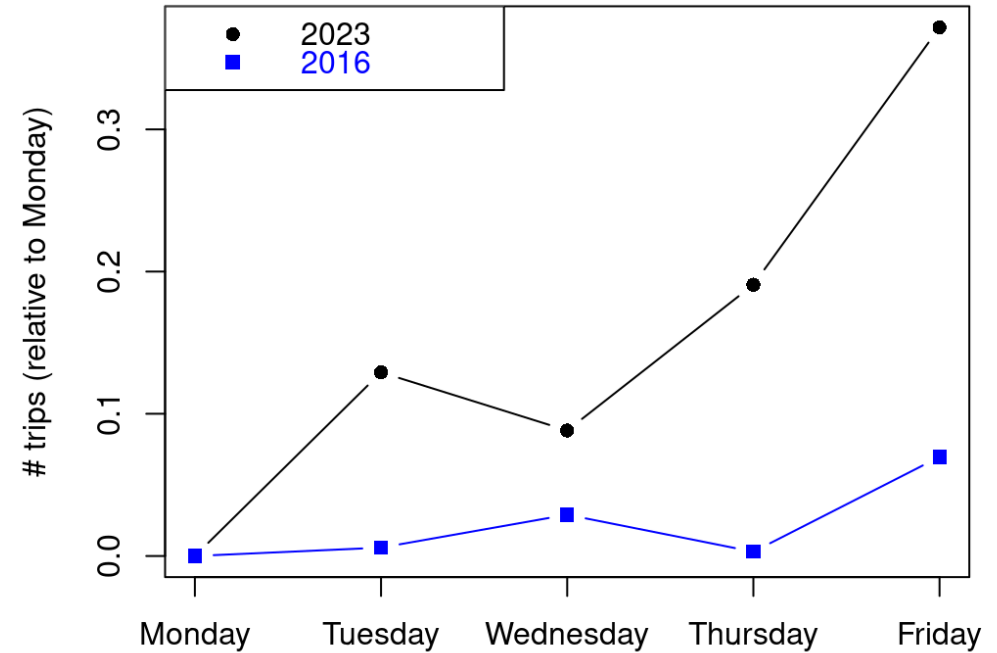
Models

- Dependent variable: daily weekday person trips by activity type (by year).
- Models:
  - Negative binomial.
  - Hurdle count:
    - Stage 1: Binomial logit: make 1 or more trips; do not make any trips.
    - Stage 2: Number of daily trips if travelling this day; truncated discrete regression (e.g., Poisson regression; negative binomial).
  - For 2023: Models extended to incorporate mixed-effects available in the week-long dataset.
    - Random intercept.
    - Additional fixed effects available in THATS:
      - Prior day trip indicator.
      - Trip made 2 days prior indicator.

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Mean number of shopping trips per weekday — Mean number of leisure/personal business trips per weekday
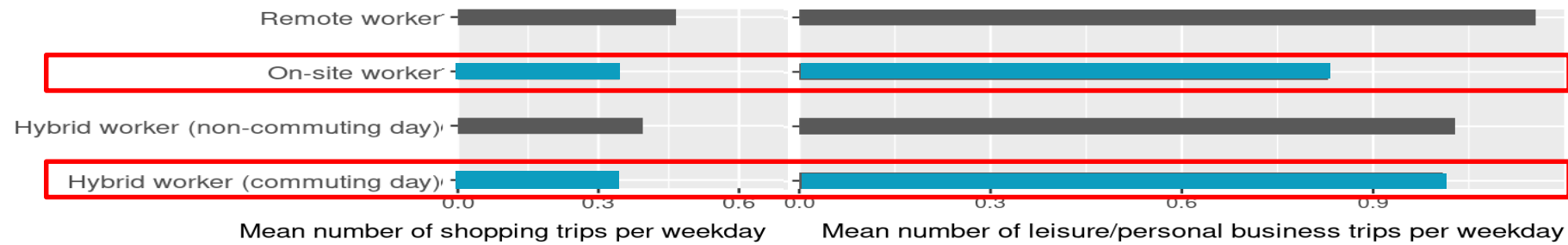
Summary of Results: Hypothesis 1

Table 4: Hypothesis 1: Activity participation of hybrid workers on commuting days is similar to that of on-site workers.

Null Hypothesis: coefficient (Hybrid) + coefficient (Hybrid & Commute) = 0

	Shopping participation			Leisure/Personal business participation		
	Neg. Binomial	Hurdle-Zero	Hurdle-Count	Neg. Binomial	Hurdle-Zero	Hurdle-Count
Value	0.0321	0.0275	0.1807	0.2837	0.2888	0.1795
Z-score	0.2906	0.2201	1.0226	3.5612	2.6930	1.8485
P-value	0.7713	0.8258	0.3065	0.0004***	0.0071**	0.0645
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1						

- Hybrid workers on commuting days & onsite workers do not have statistically significant weekday shopping participation rate differences.
- Hybrid workers on commuting days do, however, generate significantly more leisure/personal business trips than onsite workers.

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Mean number of shopping trips per weekday / Mean number of leisure/personal business trips per weekday
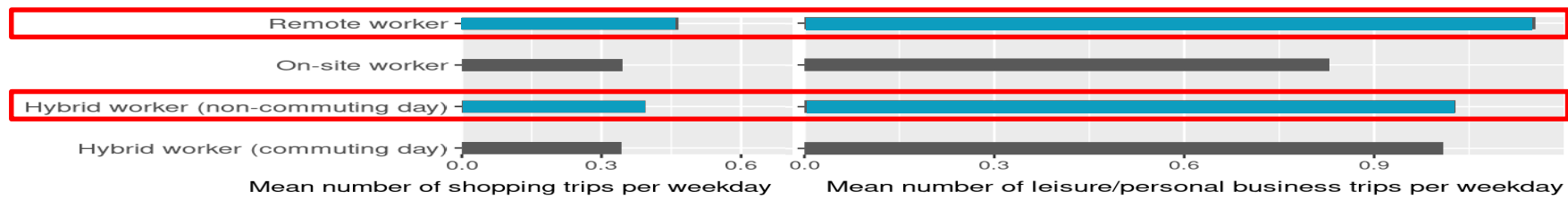
Summary of Results: Hypothesis 2

Table 5: Hypothesis 2: Activity participation of hybrid workers on non-commuting days is similar to that of remote workers.

Null Hypothesis: coefficient (Hybrid & Non-commute) – coefficient (Home) = 0

	Shopping participation			Leisure/Personal business participation		
	Neg. Binomial	Hurdle-Zero	Hurdle-Count	Neg. Binomial	Hurdle-Zero	Hurdle-Count
Value	-0.1410	-0.1054	-0.1462	-0.1215	-0.1898	-0.0536
Z-score	-1.1965	-0.7891	-0.7924	-1.2928	-1.6407	-0.4785
P-value	0.2315	0.4300	0.4281	0.1961	0.1009	0.6323
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1						

- Remote workers on average make more shopping & leisure/PB trips than hybrid non-commuters, but the differences are not significant at a 90% confidence level.
- The leisure/PB difference in making or not-making at least one weekday trip is marginally significant.

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Summary of Results: Hypothesis 3 (1)

- Remote workers are more likely to engage in both shopping & leisure/PB activities in both years.
- BUT the gap has narrowed significantly:
  - Remote workers are making fewer trips & onsite workers are making more trips.

Table 6: Negative Binomial model parameter estimation differences: 2023 vs. 2016

variables	Shopping		Leisure/Personal Business	
	b_diff	b_ratio	b_diff	b_ratio
(Intercept)	1.5706***(4.1699)	0.5911	0.6238*(2.0428)	0.7083
age	-0.0334*(-1.9823)	0.5162	0.0065(0.4681)	1.4764
driver_licTRUE	-0.3733***(-3.9762)	-0.2629	-0.2089**(-2.6863)	0.4575
emp_modalityHome	-1.1162***(-12.435)	0.2203	-0.7997***(-11.0576)	0.3476
emp_statusP	0.1085(1.1854)	2.2309	0.0231(0.2991)	1.3385
HHincome_above_100kTRUE	-0.1764**(-2.7168)	-1.0617	-0.1958***(-3.6684)	0.2501
HHincome_below_40kTRUE	-0.0168(-0.1207)	1.5736	0.3057**(2.7114)	-1.1294
I(age^2)	0.0003(1.3652)	0.5877	-0.0002(-1.2098)	2.6213
n_person	0.1213***(3.3935)	-0.2322	0.1456***(4.9092)	0.0596
n_student	-0.0223(-0.5073)	1.7481	-0.1663***(-4.5736)	-1.0460
n_vehicle	0.0418(1.0028)	4.3116	0.0122(0.3539)	1.2636
onsite_NonCommuteTRUE	-1.3289***(-14.7748)	0.0752	-1.0522***(-15.96)	0.1182
PD1TRUE	0.0503(0.5744)	0.7146	-0.1572*(-2.3419)	-0.4219
Region_TorontoTRUE	0.0102(0.1605)	0.8714	0.0804(1.5229)	2.6796
Remote_CommuteTRUE	0.4747.(1.9308)	0.5444	0.75***(5.1115)	0.1711
sexF	-0.359***(-6.4885)	-0.4782	-0.1933***(-4.2967)	-1.4903
trip_day2	0.1738*(2.1039)	5.2657	0.1035.(1.9596)	2.8132
trip_day3	0.1894*(2.2707)	-12.5191	0.0606(1.1445)	1.5480
trip_day4	0.2858***(3.4771)	-13.5799	0.203***(3.8906)	3.9995
trip_day5	0.3853***(4.8983)	3.0876	0.2148***(4.2668)	1.9493

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Summary of Results: Hypothesis 3 (2)

Mean number of shopping trips

Mean number of leisure/personal business trips
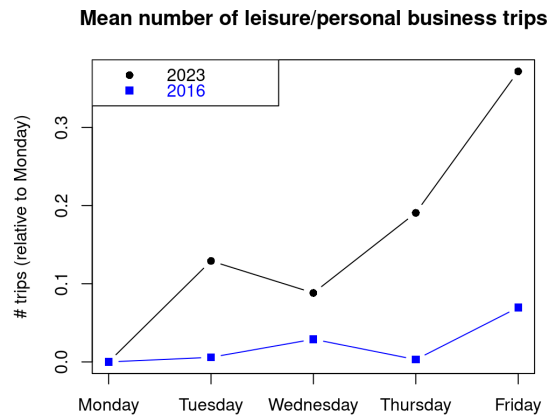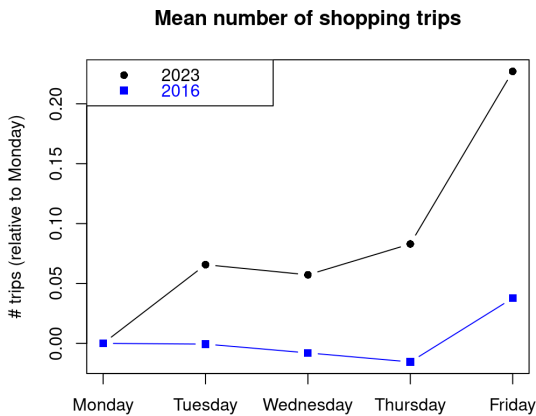
- ■ **Both shopping & leisure/PB activity participation has increased Tuesday-Friday relative to a Monday base.**
- ■ **Thursday NWS activity is notably increased.**

Table 6: Negative Binomial model parameter estimation differences: 2023 vs. 2016

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Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Summary

- Hybrid workers' shopping trips on commuting days are similar to on-site workers', and similar to remote workers' on non-commuting days.

- Regarding out-of-home leisure and personal business activity participation, hybrid workers tend to **squeeze trips on commuting days** and **favor staying at home on non-commuting days**.

- Compared to the pre-pandemic era, remote workers engage in fewer out-of-home shopping and leisure/personal business trips, potentially influenced by attractive home-based alternatives like **online shopping** or a **sedentary lifestyle** adopted during lockdown. On non-commuting days, there is a higher barrier to making trips, but once trips are initiated, their frequency exceeds that of commuting days.

- Friday traditionally experiences the highest volume of out-of-home NWS trips compared to other weekdays. In the post-pandemic era, Thursday has begun to rival Friday, indicating a shift with **"Thursday is the new Friday!"** sentiment, although the clientele is different.

- Reinforces the case for multi-day (week-long) models.

- Limitation: survey bias.

- Future work: in-home vs out-of-home activity participation
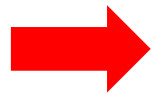
Linkages clearly exist between work modality (scheduling) and NWS activity participation that may affect activity scheduling model structures.

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Thank you.

Questions?

The regression model for negative binomial models is;

$$y_i \sim NB(\mu_i, \mu_i[1 + \alpha\mu_i]), \tag{1}$$
$$\log(\mu_i) = \beta_0 + x'_{ij}\boldsymbol{\beta} + \varepsilon_i, \tag{2}$$

and for the mixed-effect negative binomial models:

$$y_{ij} \sim NB(\mu_{ij}, \mu_{ij}[1 + \alpha\mu_{ij}]), \tag{3}$$
$$\log(\mu_{ij}) = (\beta_0 + b_i) + x'_{ij}\boldsymbol{\beta} + \varepsilon_{ij}, \tag{4}$$

where the number of trips of a given activity type made by individual i in observation j is denoted as y_i in NB models and y_{ij} in NB mixed model, $\boldsymbol{\beta}$ is the vector of fixed effects including work modalities, household attributes, and the additional dummy variables for trip making history for 2023 models, b_i is the individual-specific random effect added for 2023 mixed models, α is the dispersion parameter that captures the extent of data over-dispersion.

Hurdle count models represent the two stages of activity participation explicitly. The first stage of the process, whether to participate or not, is modeled by its zero-hurdle component, f_{zero}; and the second stage of the process, the frequency of participation given the state of participating, $\{Y|Y > 0\}$, is modelled by its positive count component, f_{count}. A general structure of hurdle models is as follows:

$$P(Y = y) = \begin{cases} f_{zero}(0) & y = 0, \\ (1 - f_{zero}(0))\dfrac{f_{count}(y)}{1 - f_{count}(0)} & y > 0. \end{cases} \tag{5}$$

In this study, we employ a logistic regression model for f_{zero}, and negative binomial regression models for f_{count}, with the same set of parameters. Similarly, for the 2023 data, the logistic regression and NB models are extended to mixed models by incorporating individual-specific random effects, similar to Equation (4). The models are fitted using maximum likelihood estimation with Laplace approximation for mixed models. The likelihood function for hurdle models is simply the multiplication of the likelihoods of two stages.

Appendix 1: Model Equations

Appendix 2: Model Estimation Results

Table 2: Out-of-home Shopping Participation Estimation

Variables	NB Model	2016 Hurdle Model Zero	2016 Hurdle Model Count	NB Mixed Model 2023	Hurdle Mixed Model Zero	Hurdle Mixed Model Count
(Intercept)	-3.8411***(0.779)	-4.2493***(0.469)	-3.4166**(0.1385)	-2.2706***(0.3685)	-2.6864***(0.4232)	-0.8871(0.573)
I(age^2)	-0.0006***(0)	-0.0007	-0.0003	-0.0004(0.0002)	-0.0005(0.0002)	-0.0001(0.000)
age	0.069***(0.0031)	0.0816	0.0321***(0.0013)	0.0356*(0.0165)	0.0448*(0.0191)	0.0102(0.024)
sexF	0.2429***(0.0129)	0.2864***(0.0146)	0.1058***(0.0317)	-0.1161*(0.0538)	-0.0995(0.0618)	-0.1394(0.08)
sexO				-0.1146(0.2421)	-0.1211(0.277)	-0.1892(0.383)
emp statusP	0.0882***(0.0176)	0.1175***(0.02)	0.0208(0.0382)	0.1967*(0.0899)	0.2917**(0.1034)	-0.0518(0.13)
emp modalityHome	1.4316***(0.0215)	1.7995***(0.0237)	0.4918***(0.0478)	0.3154***(0.0872)	0.1867(0.0993)	0.5409***(0.134)
emp modalityHybrid				0.1744(0.0793)	0.0813(0.0894)	0.4037**(0.126)
trip day2	0.0408(0.022)	0.0437(0.0255)	0.0159(0.0539)	0.2145*(0.0796)	0.2348**(0.0906)	0.0950(0.129)
trip day3	-0.0140(0.0222)	-0.018(0.0256)	-0.0396(0.0549)	0.1754*(0.0804)	0.259*(0.091)	-0.0659(0.133)
trip day4	-0.0196(0.0204)	-0.0193(0.0236)	-0.0485(0.0505)	0.2662**(0.0796)	0.3052***(0.0909)	0.1370(0.128)
trip day5	0.1846***(0.0196)	0.1948***(0.0228)	0.1564***(0.0471)	0.5698***(0.0762)	0.647**(0.0875)	0.2679*(0.119)
Hybrid CommuteTRUE				-0.1423(0.0768)	-0.1087(0.087)	-0.223(0.123)
driver licTRUE	0.2956***(0.0309)	0.3311***(0.0344)	0.1545(0.0823)	-0.0777(0.0887)	-0.0714(0.1022)	-0.1183(0.132)
n vehicle	0.0126(0.0075)	0.001(0.009)	0.0596**(0.0187)	0.0545(0.041)	0.0979(0.0471)	-0.0654(0.060)
n person	-0.0984***(0.0075)	-0.0915**(0.0085)	-0.1132***(0.0189)	0.0229(0.0349)	0.0164(0.0404)	0.0371(0.051)
n student	-0.0298*(0.0098)	-0.0699***(0.0112)	0.0768**(0.0242)	-0.0521(0.0428)	-0.052(0.0494)	-0.0177(0.063)
PD1TRUE	-0.1761***(0.0352)	-0.1818***(0.0399)	-0.1955*(0.0927)	-0.1258(0.0801)	-0.0952(0.0911)	-0.1515(0.126)
Region TorontoTRUE	-0.0795***(0.0151)	-0.0829**(0.0175)	-0.0769*(0.0369)	-0.0693(0.0619)	0.0088(0.0713)	-0.2282*(0.091)
HHincome above 100kTRUE	0.0856***(0.0136)	0.0904**(0.0157)	0.0605(0.0333)	-0.0909(0.0635)	-0.0862(0.0727)	-0.1025(0.095)
HHincome below 40kTRUE	-0.0293(0.0239)	-0.015(0.0279)	-0.0669(0.0577)	-0.0461(0.1371)	-0.0116(0.1575)	-0.1225(0.207)
onsite NonCommuteTRUE	-0.4534***(0.0139)	1.7156***(0.0164)	-0.1811**(0.0343)	0.108(0.0886)	-0.1399(0.1019)	0.713***(0.140)
Remote CommuteTRUE	-0.0094***(0.0142)	-1.4213***(0.0555)	-0.2881(0.0353)	-0.5671*(0.2411)	-0.5321*(0.2691)	-0.4901(0.428)
trip Yes 1dBTRUE				0.3312***(0.0663)	0.3817***(0.0819)	0.1066(0.082)
trip Yes 2dBTRUE				0.3178***(0.0614)	0.4013***(0.0731)	0.0563(0.08)
nonrespondTRUE	-0.4534***(0.0139)	-0.5284***(0.015)	0.6691***(0.0343)			
survey methodTelephone	-0.0094(0.0142)	0.064**(0.0164)	-0.2162**(0.0353)			
Dispersion parameter	1.25		0.211	0.664		1.
Random effects: hhper ID				0.1607(0.4009)	0.2416(0.4915)	0.0848(0.291)
# records	172244		172244	7880		78
AIC	160609		158879.2	12564.2		12521
BIC	160840.3		159311.6	12752.4		12891
Log Likelihood	-80281.5		-79396.6	-6255.1		-6207

Note: Standard errors are reported in parentheses. For random effects, variance and Std.Dev are reported.
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 3: Out-of-home leisure/personal business participation estimation

Variables	NB Model	2016 Hurdle Model Zero	2016 Hurdle Model Count	NB Mixed Model 2023	Hurdle Mixed Model Zero	Hurdle Mixed Model Count
(Intercept)	-2.138***(0.0563)	-2.3131***(0.041)	-2.4059***(0.0912)	-1.5145***(0.3001)	-1.9190***(0.3584)	-0.2933(0.3471)
I(age^2)	-0.0001***(0)	-0.00017	-0.000074	-0.0003*(0.0002)	-0.0003(0.0002)	0(0.0002)
age	0.0136***(0.0023)	0.018505	0.0119***(0.0009)	0.0201(0.0137)	0.0236(0.0162)	-0.0041(0.0157)
sexF	0.0776***(0.0099)	0.1041***(0.0124)	0.021(0.0231)	-0.1157***(0.0439)	-0.0726(0.0525)	-0.1115*(0.05)
sexO				-0.0974(0.1913)	-0.1784(0.2296)	0.0519(0.2197)
emp statusP	0.0682***(0.0141)	0.0512**(0.0176)	0.0978***(0.0286)	0.0913(0.0799)	0.1741(0.0909)	-0.0055(0.0876)
emp modalityHome	1.226***(0.0175)	1.748***(0.0255)	0.5281***(0.0367)	0.426***(0.0702)	0.366**(0.0866)	0.4096***(0.0827)
emp modalityHybrid				0.3045**(0.0625)	0.1762*(0.0768)	0.356***(0.0756)
trip day2	0.0571***(0.0173)	0.0729***(0.0216)	0.0214(0.041)	0.1606**(0.0499)	0.2761***(0.0785)	0.119(0.0641)
trip day3	0.1106***(0.0171)	0.1394***(0.0214)	0.0598(0.0401)	0.1711***(0.0501)	0.3234**(0.079)	0.1377(0.0643)
trip day4	0.0677***(0.0159)	0.0616**(0.0199)	0.1101**(0.0375)	0.2706**(0.0497)	0.4726**(0.0793)	0.1603*(0.0633)
trip day5	0.2263***(0.0154)	0.2898***(0.0194)	0.1338***(0.036)	0.4411***(0.0479)	0.68555**(0.0789)	0.2925***(0.0599)
Hybrid CommuteTRUE				-0.0208(0.0404)	0.1127(0.0749)	-0.1766*(0.061)
driver licTRUE	0.3851***(0.024)	0.4623***(0.0286)	0.2312***(0.0606)	0.1762*(0.074)	0.1974*(0.0873)	0.0512(0.0872)
n vehicle	0.0461***(0.0058)	0.0586***(0.0076)	0.0345*(0.0138)	0.0583(0.0338)	0.0734(0.0404)	0.02(0.0385)
n person	-0.1548***(0.0059)	-0.1972***(0.0073)	-0.0556***(0.0137)	-0.0092(0.0291)	-0.0348(0.0348)	0.0047(0.0329)
n student	0.0813***(0.0074)	0.082**(0.0093)	0.0644***(0.0174)	-0.085*(0.0356)	-0.0934*(0.0424)	-0.0366(0.0404)
PD1TRUE	0.1106***(0.024)	0.1661***(0.0301)	-0.0333(0.0565)	-0.0466(0.0627)	0.0478(0.0755)	-0.1148(0.0709)
Region TorontoTRUE	0.0479***(0.0116)	0.0656***(0.0146)	0.0361(0.0269)	0.1282*(0.0515)	0.0611(0.0612)	0.1201*(0.059)
HHincome above 100kTRUE	0.2612***(0.0104)	0.3478***(0.013)	0.0616*(0.0243)	0.0653(0.0524)	0.0816(0.0622)	0.0001(0.0602)
HHincome below 40kTRUE	-0.1436***(0.0197)	-0.1798***(0.025)	-0.0715(0.0456)	0.1621(0.111)	0.0433(0.1342)	0.2642*(0.1252)
onsite NonCommuteTRUE	1.193***(0.0124)	1.5947***(0.017)	0.6167***(0.0266)	0.1411*(0.0647)	-0.235*(0.0891)	0.6151***(0.0832)
Remote CommuteTRUE	-0.9049***(0.0379)	-1.4181***(0.0493)	-0.2676***(0.0852)	-0.1549(0.1418)	-0.1023(0.2148)	-0.207(0.1715)
trip Yes 1dBTRUE				0.3204***(0.0412)	0.8128**(0.0632)	0.2266***(0.0427)
trip Yes 2dBTRUE				0.2879***(0.0394)	0.7773***(0.0573)	0.129**(0.0426)
nonrespondTRUE	-0.3298***(0.0107)	-0.3672***(0.013)	-0.321**(0.0253)			
survey methodTelephone	0.2125***(0.0108)	0.2817***(0.0136)	0.096**(0.0248)			
Dispersion parameter	2.11		0.441	1.94		4.21
Random effects: hhper ID				0.3507(0.5922)	0.08388(0.2896)	0.2526(0.5026)
# records	172244		172244	7880		7880
AIC	234293.7		222322.9	20908.6		20368.7
BIC	234525		222755.4	20786.9		20738.2
Log Likelihood	-1121238		-111118.5	-10272.3		-10131.3

Note: Standard errors are reported in parentheses. For random effects, variance and Std.Dev are reported.
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1