Water Conservation and Persuasion in Kelowna: Persistence Pays.

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Questions

- What type of behavior is water conservation?
  - Saving money?
  - Environmental concern?
- How are choices connected?
  - Substitutes or complements?
  - Ordered?
- What drives conservation choices?

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Understanding Conservation

- Behavior and investment
  - Shorter showers
  - Low flow shower heads
- Differing impacts
  - Water saving
    - Money saving?
  - Time saving or using
    - Substitute time for water
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Model

- Choose
  - set of conservation activities and investments ($\boldsymbol{y} = [y_1, y_2, \ldots, y_K]$, $y_i \in \{0, 1\}$),
  - set of other consumption activities ($\boldsymbol{x} \in (\mathbb{R}^+)^N$),
  - leisure ($l \in [0, T]$).
- To maximize utility ($u(\boldsymbol{x}, \boldsymbol{y}, l)$)
- Subject to income exceeding sum of
  - cost of water conservation ($c(\boldsymbol{y})$),
  - cost of other consumption activities ($\boldsymbol{p}'\boldsymbol{x}$),
  - value of water savings ($qs(\boldsymbol{y})$),
  - lost wages from leisure time (wl),
  - net time value of conservation activites ($wt(\boldsymbol{y})$).

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Continuous Choice

- Level of activity increases when
  1. Cheaper,
  2. Needs less time (or saves more time),
  3. Higher water price
  4. More 'feel good' from activity
  5. Higher income (if marginal benefit of other consumption decreasing with greater consumption).

Discrete Choice

- More likely to choose activity if
  1. Cheaper,
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- Discrete choices may interact
  - rain barrels and xeriscape yard (complements?)
  - vs rain barrels and gravel / paved yard (substitutes?)
  - vs high efficiency laundry and dual flush toilet (independent?)

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Discrete Choice

- Choices may be independent.
- Choices normally not exclusive.
  - high efficiency laundry and dual flush toilet.
    - None, one of, or both.
- Choices ordered?
  - utility benefit per unit cost
    - utility unobservable
    - cost, time saving/cost, water saving, ... weakly observable, dependent on behaviors
- perfect ordering unlikely
  - Evidence for some ordering?

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Choice Ordering

- Evidence for ordering.
  - Optimal ordering unique to each household
    - Capital replacement, household composition, ...
  - Enough similarity that data ordered?
- If data ordered, treat like count data
  - Model number as function of exogenous drivers.

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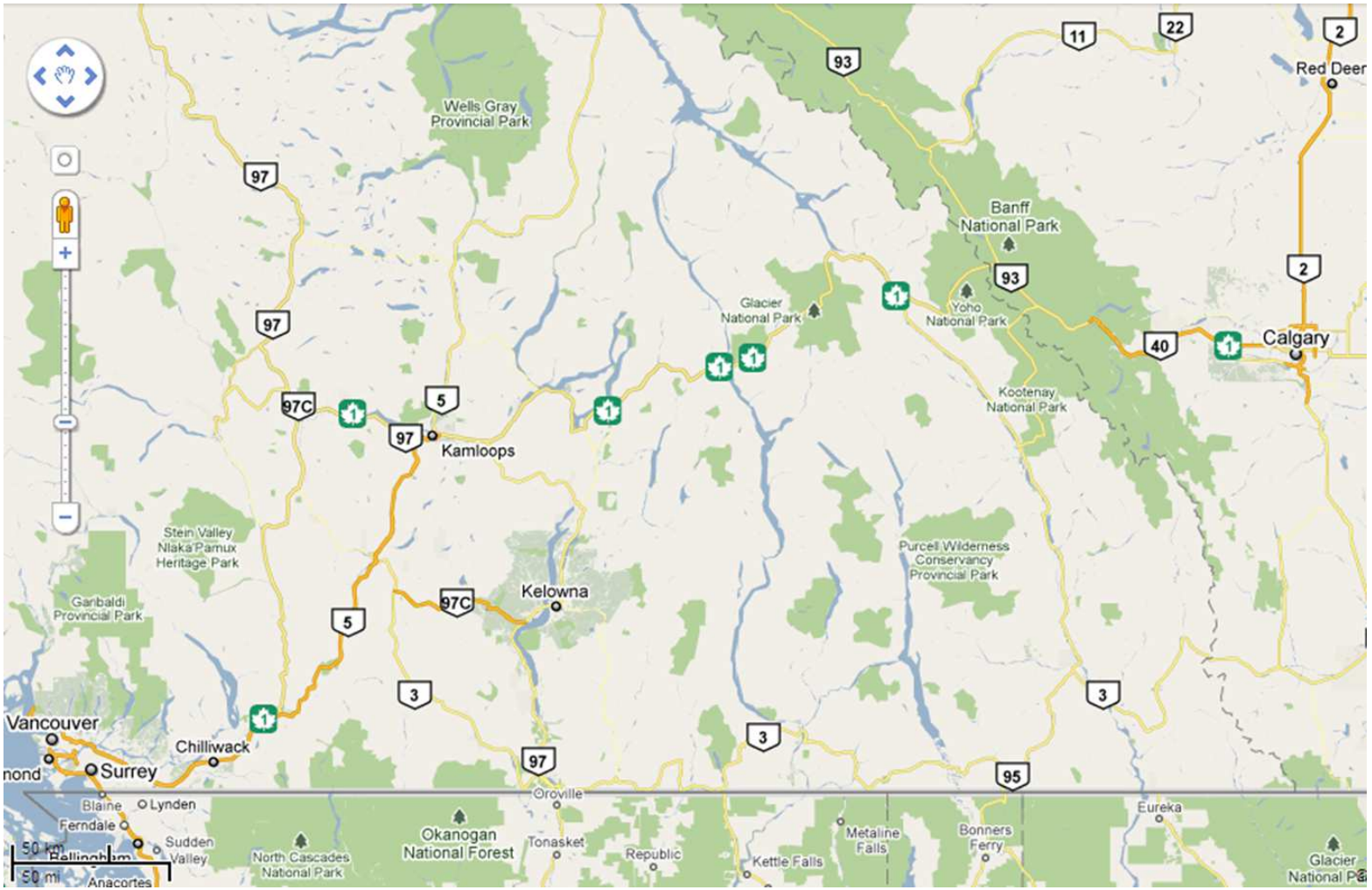
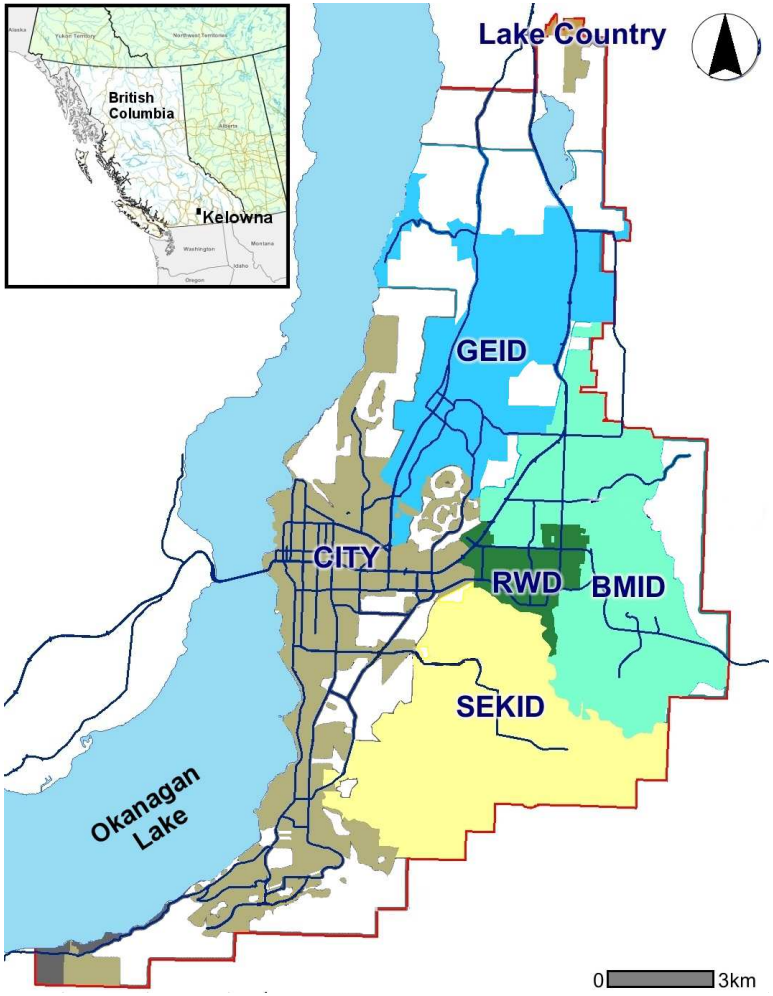
Location


Wells Gray Provincial Park
Banff National Park
Glacier National Park
Yoho National Park
Kootenay National Park
Purcell Wilderness Conservancy Provincial Park
Stein Valley Nlaka'pamux Heritage Park
Garibaldi Provincial Park
North Cascades National Park
Okanogan National Forest
Kamloops
Kelowna
Calgary
Red Deer
Vancouver
Surrey
Chilliwack
Oroville
Tonasket
Republic
Kettle Falls
Metaline Falls
Bonners Ferry
Eureka
Glacier National Pa
Blaine
Lynden
Ferndale
Sudden Valley
Anacortes
50 km
50 mi
97
97C
5
3
95
93
11
22
2
40

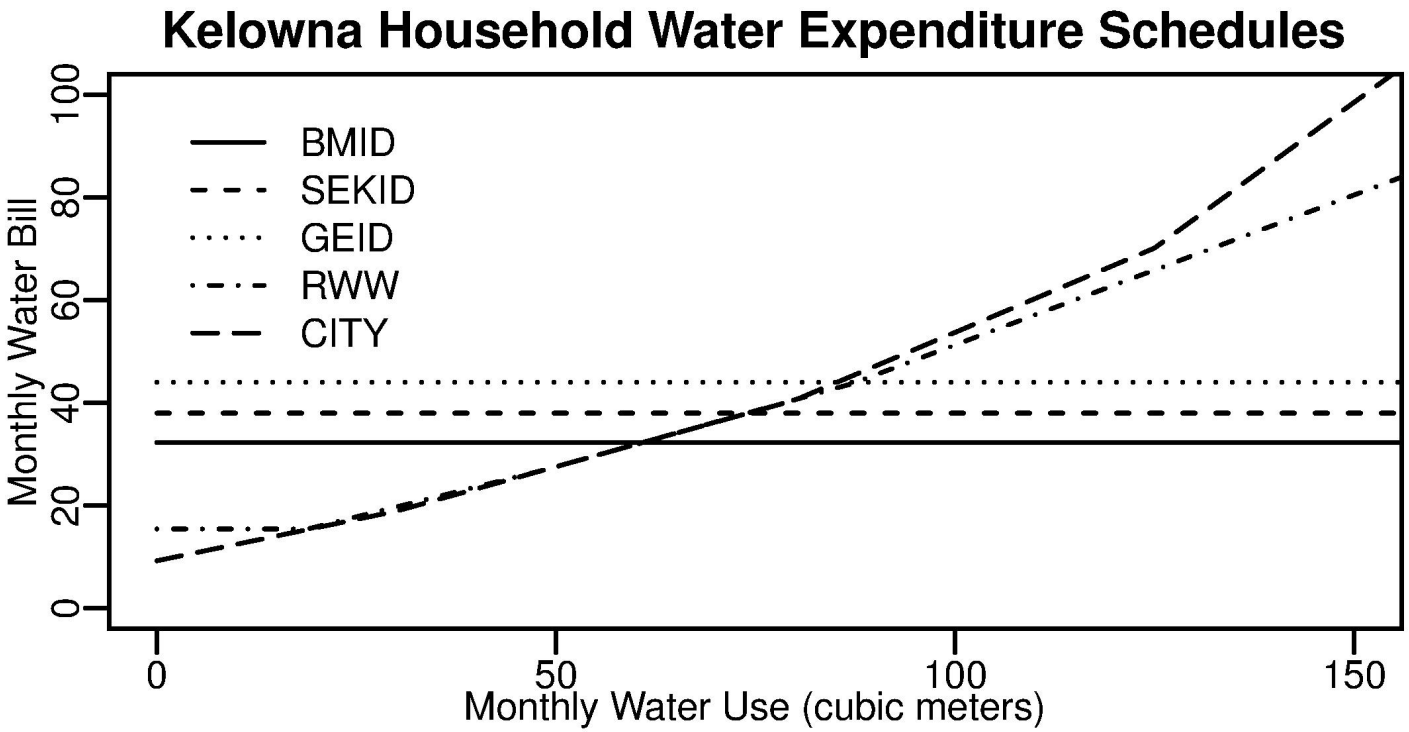
Location

- Kelowna, British Columbia, Canada
  - Semi-arid: ~320mm annual precipitation.
  - Rapid population growth: 9.3% growth, 2006 to 2011.
    - 107,280 $\rightarrow$117,310.
  - Vulnerable to climate change.
  - Five water providers.
    - Volumetric pricing, two.
    - Flat fee, three.

Location


British Columbia
Kelowna
Lake Country
GEID
CITY
RWD
BMID
SEKID
Okanagan Lake
0
3km

Location


Kelowna Household Water Expenditure Schedules
Monthly Water Bill
0
20
40
60
80
100
BMID
SEKID
GEID
RWW
CITY
0
50
100
150
Monthly Water Use (cubic meters)

Data Collection

- Mixed mode survey (telephone, internet, mail).
  - Initially telephone and internet, changed to mail and internet.
  - Summer 2009 to autumn 2010.
  - 2273 contacted, 512 completed.
    - Response rate ~25%
    - Not in service, respondent moved, etc.,

Indoor Conservation

N	Tap Aerator	**Low fl. Shower**	Low fl. Toilet
516	196	**366**	294
1.00	0.38	**0.71**	0.57

	Effic. Washer	Effic. D. Washer	**Grey System**
	245	212	**5**
	0.47	0.41	**0.01**

Outdoor Conservation

N	Water Less	Low wat. Grass	Moisture Probe	**Timed Irrig**	Rain Barrel
516	261	69	12	**356**	61
1.00	0.51	0.13	0.02	**0.69**	0.12

	Grey System	Soil Amend	Pool Cover	Gravel	Xeriscape
	2	200	58	164	134
	0.00	0.39	0.11	0.32	0.26

Conservation Behaviors

N	Scrape Dishes	Wash in Basin	Off Teeth
516	257	203	414
1.00	0.50	0.39	0.80

Shower Off	Yellow Mellow	D. Washer Full	**Washer Full**
74	248	435	**455**
0.14	0.48	0.84	**0.88**

By Provider

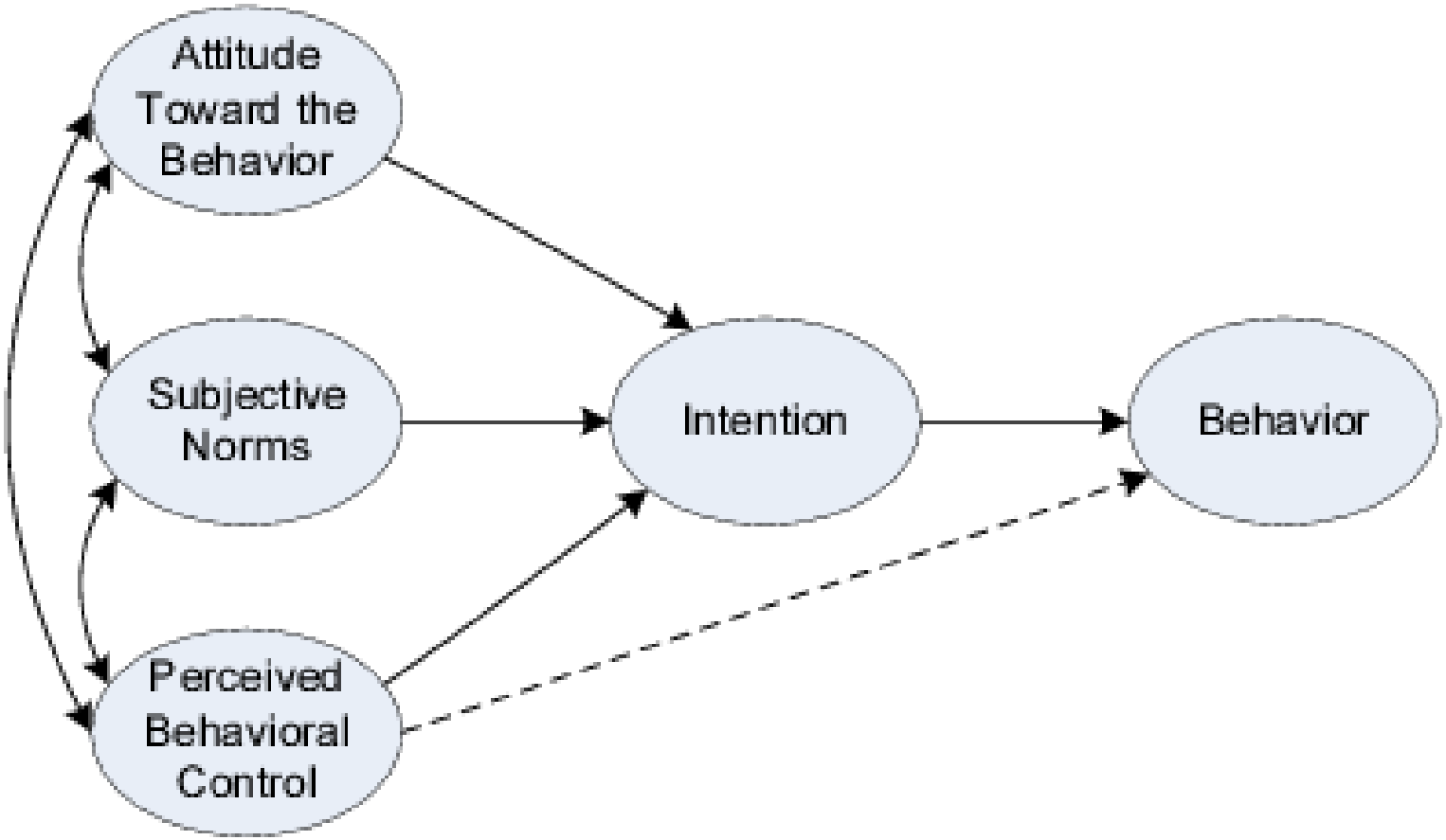
Variable	BMID	CITY	GEID	OTHER	RWW	SEKID
IN_HSE (516)	2.75	2.62	2.44	2.25	2.43	2.66
ON_YRD (516)	2.52	2.59	2.51	2.69	2.49	2.80
BEHAVE (516)	4.29	4.02	4.01	3.88	3.71	4.29

- Invesments (IN_HSE, ON_YRD), no difference.
- Behaviors, no difference.

Choice Sequence

- Start with trial sequence, $y_1, y_2, y_3, \ldots, y_N$
- Count matching sequences
  - Matches, $1, 1, 1, 0, 0, \ldots, 0$
  - Does not match, $1, 0, 1, 1, 0, \ldots, 0$
- Null, data random.
  - Count frequency that random draws match
    - Sample preserving observation counts
    - Sample uniformly across options
- Compare observed to trial and null.
- Also with allowance for perturbations.

Theory of Planned Behavior



Ajzen, 1991.

Variables

Category	Variable
Attitudes and Norms	NEP, GROW_BAD, ABUNDANCE, OTHERS_CONS, LEADER, VOTECON, HEREEND, HEREWEATHER, HERELEIS, MALE
Perceived Control	KNOW, EDUC, MSG_PRIV, MSG_SOC, *PAY_WAT, INCOME*
Intention	COMPULSION, BEHAVE
Behavior	IN_HOUSE, ON_YARD, BEHAVE

Econometric Model

- Two stage least squares
- First stage

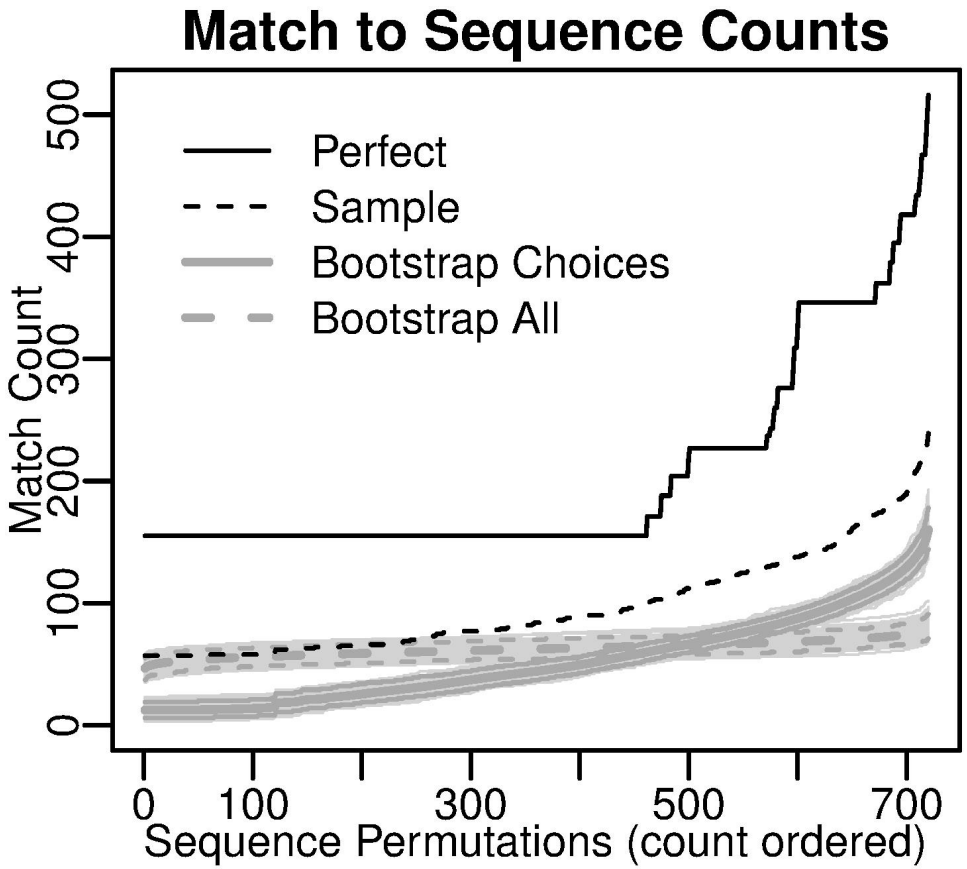
$$\text{COMPULSION} = f(\boldsymbol{X})$$

- Second stage

$$\begin{bmatrix} \text{IN\_HOUSE} \\ \text{ON\_YARD} \\ \text{BEHAVE} \end{bmatrix} = \begin{bmatrix} g_{IN}(\text{COMP}\hat{\text{U}}\text{LSION}, \boldsymbol{Z}_{IN}) \\ g_{ON}(\text{COMP}\hat{\text{U}}\text{LSION}, \boldsymbol{Z}_{ON}) \\ g_{BE}(\text{COMP}\hat{\text{U}}\text{LSION}, \boldsymbol{Z}_{BE}) \end{bmatrix}$$

- For system, estimate by SUR and 3SLS.

Choice Ordering



Area Measure

			Column		All	
	Sample	Perfect	$\overline{\mu^*}$	$\overline{\sigma^*}$	$\overline{\mu^*}$	$\overline{\sigma^*}$
Exhaustive calculation						
IN_HOUSE	0.188	0.397	0.101	0.006	0.122	0.008
BEHAVE	0.108	0.318	0.053	0.004	0.074	0.006
Bootstrap, 200 samples of 500 sequences, 39 bootstrap samples						
IN_HOUSE	0.188	0.397	0.101	0.006	0.121	0.008
ON_YARD	0.123	0.340	0.058	0.007	0.077	0.008
BEHAVE	0.108	0.318	0.053	0.004	0.073	0.006

Maximum Match Measure

	Sample	Perfect	Column $\overline{\mu^*}$	Column $\overline{\sigma^*}$	All $\overline{\mu^*}$	All $\overline{\sigma^*}$
Exhaustive calculation						
IN_HOUSE	239	516	160.12	9.99	80.4	5.87
BEHAVE	232	516	166.94	10.08	54.7	4.24
Bootstrap, 200 samples of 500 sequences, 39 bootstrap samples						
IN_HOUSE	236.0	508.3	158.8	9.48	79.6	5.13
ON_YARD	163.3	361.2	115.0	8.94	51.5	4.59
BEHAVE	214.1	480.8	158.3	9.49	52.3	3.95

First Stage

	COMPULSION		log(BEHAVE)	
	β	*se*	β	*se*
(Intercept)	**3.1127*****	**0.6426**	**0.9782*****	**0.2120**
NEP	**0.2027****	**0.0701**	-0.0187	0.0231
MSG_PRIV	-0.0027	0.0289	**0.0190***	**0.0095**
MSG_SOC	0.0779	0.0491	**0.0407***	**0.0162**
KNOW	0.1826	0.2496	-0.0288	0.0823
LEADER	0.0228	0.0318	**0.0187**$^{\cdot}$	**0.0105**
EDUC	-0.0045	0.0340	0.0035	0.0112
GROW_BAD	**0.2083*****	**0.0611**	0.0283	0.0201
ABUNDANCE	**-0.1582*****	**0.0448**	0.0005	0.0148
VOTECON	**0.1625**$^{\cdot}$	**0.0945**	0.0352	0.0312

First Stage

	COMPULSION		log(BEHAVE)	
	β	*se*	β	*se*
OTHERS_CONS	**0.1236****	**0.0444**	**0.0399****	**0.0146**
HEREENV	-0.0193	0.1131	-0.0322	0.0373
HEREWEATH	0.0603	0.1112	-0.0301	0.0367
HERELEIS	0.0238	0.0950	0.0027	0.0313
PAY_WAT	-0.0841	0.0949	-0.0283	0.0313
INCOME	0.8398	0.9625	-0.2634	0.3176
ASSESS	-0.0962	0.1918	0.0931	0.0633
BLDSIZE	2.8228	8.2942	2.8631	2.7367
BLDAGE	0.4110	0.8329	0.1634	0.2748
BLDAGE2	-1.1225	1.1235	-0.1818	0.3707

First Stage

	COMPULSION		log(BEHAVE)	
	β	se	β	se
OCCUPANTS	0.0276	0.0506	**0.0620*****	**0.0167**
MALE	-0.1017	0.1010	-0.0188	0.0333
LOTSIZE	0.2347	0.2548	0.0530	0.0841
SCHOOL	-0.0302	0.1293	**-0.0870***	**0.0426**
RETIRED	0.1819	0.1215	0.0456	0.0401
YEARS_KEL	-0.4065	0.3424	-0.0781	0.1130
	$R^2 = 0.306$		$R^2 = 0.199$	
	$F_{23,276} = 4.826$		$F_{23,276} = 2.723$	

IN_HOUSE

	3SLS		NLS SUR		NLS 3SLS	
	β	*se*	β	*se*	β	*se*
(Intercept)	**0.963***	**0.490**	**0.653***	**0.262**	0.470	0.612
log(BEHAVE)	**0.667**$^{+}$	**0.398**	**0.447*****	**0.124**	**0.851**$^{+}$	**0.455**
COMPULSION	**-0.144***	**0.064**	**-0.057**$^{+}$	**0.031**	**-0.141***	**0.063**
PAY_WAT	-0.001	0.054	0.006	0.054	-0.010	0.057
INCOME	**1.436***	**0.565**	**1.132***	**0.527**	**1.432***	**0.585**
ASSESS	**-0.209**$^{+}$	**0.112**	**-0.260**$^{+}$	**0.138**	**-0.281***	**0.141**
BLDSIZE	1.312	4.462	2.094	4.791	3.000	4.939
BLDAGE	**-0.787**$^{+}$	**0.434**	**-1.112****	**0.423**	**-1.009***	**0.445**
BLDAGE2	**1.155**$^{+}$	**0.594**	**1.426****	**0.544**	**1.399***	**0.566**

IN_HOUSE

	3SLS		NLS SUR		NLS 3SLS	
	β	*se*	β	*se*	β	*se*
OCCUPANTS	-0.004	0.027	0.020	0.022	0.004	0.026
MSG_PRIV	**0.033**$^{+}$	**0.017**	**0.042***	**0.016**	0.030	0.020
MSG_SOC	-0.013	0.030	-0.028	0.027	-0.031	0.032
KNOW	-0.081	0.138	-0.174	0.145	-0.128	0.152
EDUC	0.002	0.018	-0.001	0.019	-0.001	0.020
R^2	0.0849		0.1232		0.0755	

ON_YARD

	3SLS		NLS SUR		NLS 3SLS	
	β	*se*	β	*se*	β	*se*
(Intercept)	0.396	0.448	-0.275	0.299	0.970	0.577
log(BEHAVE)	0.295	0.308	**0.534*****	**0.145**	0.008	0.390
COMPULSION	0.001	0.061	0.022	0.036	-0.042	0.077
PAY_WAT	-0.051	0.053	-0.017	0.061	-0.080	0.066
INCOME	0.674	0.526	**1.092**$^{+}$	**0.558**	0.864	0.615
ASSESS	0.132	0.105	0.076	0.091	0.131	0.107
LOTSIZE	0.065	0.133	0.062	0.125	0.077	0.134
MSG_PRIV	0.019	0.016	0.007	0.018	0.008	0.020
MSG_SOC	**0.085****	**0.029**	**0.092*****	**0.028**	**0.124*****	**0.033**

ON_YARD

	3SLS		NLS SUR		NLS 3SLS	
	β	*se*	β	*se*	β	*se*
KNOW	0.179	0.136	0.094	0.161	0.038	0.175
EDUC	0.011	0.018	0.002	0.021	0.001	0.023
R^2	0.1632		0.1547		0.0879	

BEHAVE

	3SLS		NLS SUR		NLS 3SLS	
	β	*se*	β	*se*	β	*se*
(Intercept)	**0.993*****	**0.191**	**0.827*****	**0.132**	**0.936*****	**0.205**
COMPULSION	**0.074***	**0.033**	**0.065*****	**0.019**	0.055	0.036
PAY_WAT	-0.034	0.031	-0.028	0.031	-0.040	0.032
INCOME	-0.119	0.289	-0.071	0.294	-0.168	0.299
OCCUPANTS	**0.059*****	**0.016**	**0.055*****	**0.015**	**0.053*****	**0.016**
SCHOOL	**-0.076**$^{+}$	**0.040**	**-0.072**$^{+}$	**0.041**	**-0.072**$^{+}$	**0.041**
RETIRED	0.028	0.038	0.028	0.039	0.018	0.040
YEARS_KEL	-0.011	0.098	0.031	0.103	-0.007	0.104
MSG_PRIV	**0.017**$^{+}$	**0.009**	**0.022***	**0.010**	**0.021***	**0.010**
MSG_SOC	**0.037***	**0.016**	**0.038***	**0.016**	**0.042****	**0.016**

BEHAVE

	3SLS		NLS SUR		NLS 3SLS	
	β	*se*	β	*se*	β	*se*
KNOW	-0.039	0.081	-0.044	0.084	-0.060	0.085
EDUC	0.006	0.011	0.008	0.011	0.006	0.011
R^2	0.1465		0.1588		0.1555	

System Results

- Sargan tests for overidentifying restrictions.
  - Significant without instruments,
  - Insignificant when instruments included.
- Hausmann tests for endogeneity
  - Failed to reject, instruments not endogenous?
- Cragg-Donal tests for weak instruments
  - Instruments weak
- OLS may be just as good as other approaches.

Conclusion

- Conservation activities are weakly ordered.
- Messages about conservation important.
  - Social context of activity and message related.
- Message impact not via compulsion / behavior
  - TBP not supported
  - Endogeneity tests weak
- No evidence for price effect.
  - Price too low?
  - Price dominated by messaging / social pressure.