Lecture 5: Estimating Demand Functions with Travel Cost Models

Prof. Theising
Environmental Economics
Econ 4075

The Travel Cost Model

- In June of 1947, the National Parks Service, headed by Arthur Demaray, reached out to a group of economists to ask about the feasibility of estimating the economic value of the national park system.

- In response they received 10 letters. One of these letters was from Harold Hotelling.

The University of North Carolina
Institute of Statistics
Chapel Hill

DEPARTMENT OF MATHEMATICAL STATISTICS

June 18, 1947

Mr. Newton B. Drury, Director
National Park Service
Department of the Interior
Washington 25, D. C.

Dear Mr. Drury:

After a letter from Mr. A. E. Demaray, and a conference with Dr. Roy A. Pruitt of the National Park Service, I am convinced that it is possible to set up appropriate measures for evaluating, with a reasonable degree of accuracy, the service of national parks to the public.

The development of criteria for evaluating benefits to the public has been a long-term interest of mine. Following the example set a hundred years ago by the French engineer, Jules Dupuit, who wrote formulae for the benefits of roads, bridges, and canals, I have worked out more general formulae for benefits from wider and more complicated classes of public services.

These formulae, of course, involve coefficients which must, in each case, be determined by factual statistical studies. The development of such studies I believe to be possible through several modes of attack which Dr. Pruitt and I discussed. One of these, of whose feasibility I am confident, and which might be pursued further, is as follows:

Let concentric zones be defined around each park so that the cost of travel to the park from all points in one of these zones is approximately constant. The persons entering the park in a year, or a suitably chosen sample of them, are to be listed according to the zone from which they come. The fact that they come means that they service of the park is at least worth the cost, and this cost can probably be estimated with fair accuracy. If we assume that the benefits are the same no matter what the distance, we have, for those living near the park, a consumers' surplus consisting of the differences in transportation costs. The comparison of the cost of coming from a zone with the number of people who do come from it, together with a count of the population of the zone, enables us to plot one point for each zone on a demand curve for the service of the park. By a judicious process of fitting it should be possible to get a good enough approximation to this demand curve to provide, through integration, a measure of the consumers surplus resulting from the availability of the park. It is this consumers surplus (calculated by the above process with deduction for the cost of operating the park) which measures the benefits to the public in the particular year. This, of course, might be capitalized to give a capital value for the park, or the annual measure of benefit might be compared directly with the estimated annual benefits on the hypothesis that the park area was used for some alternate purpose.

Overview: Travel Cost Method

- The travel cost approach typically uses data on recreational visitation to measure the revealed value of the recreational site and its amenities

- Key idea: travel costs (time, $, effort) that people incur to use a recreational site effectively gives us variation in access prices

- We can estimate WTP based on the amount of visits that the general population makes to sites of different prices

- From the demand curve, we can value benefits or values of:
  - Opening/closure of a site/sites
  - Changes in environmental quality at a site/sites
  - Changes is cost of access for a site/sites

Theoretical model

Consider the case of a single consumer and a single recreational site.

Consumer's problem (building from labor econ theory…) is to optimize their time allocation as a function of:

- Total # of recreational trips: x, to a site of quality q, with per-trip time cost t
- Total endowment of time: T
- Time spent working: H
- Non-recreation, non-work time: l
- Per-time-unit wage: w
- Monetary cost of reaching the site: c

Theoretical model (cont.)

Consumer solves the utility maximization problem:

$$\max_{z,x,l} U(x, z, l, q) \qquad s.t. \qquad \underbrace{wH = cx + z}_{(money\ budget)}, \qquad \underbrace{T = H + l + tx}_{(time\ budget)}$$

Theoretical model (cont.)

Consumer solves the utility maximization problem:

$$\max_{z,x,l}\ U(x,z,l,q) \qquad s.t. \qquad \underbrace{wH = cx + z}_{(money\ budget)}, \qquad \underbrace{T = H + l + tx}_{(time\ budget)}$$

Combining the money and time budgets:

$$\max_{z,x,l}\ U(x,z,l,q) \qquad s.t. \qquad \underbrace{wT = (c + wt)x + z + wl}_{(combined\ budget)}$$

Other notes: ***z*** is numeraire consumption, ***wT*** is the money value of consumer's total time budget, ***c + wt*** is the total cost to reach site, ***wl*** is the opportunity cost of non-recreational leisure.

Theoretical model (cont.)

Denote $Y = wT$ (consumer's full income) and $p = c + wt$ (full travel cost)

$$\max_{z,x,l} U(x, z, l, q) \qquad s.t. \qquad \underbrace{Y = px + z + wl}_{(combined\ budget)}$$

A bit more algebraic substitution yields:

$$\max_{x,l} U(x, Y - px - wl, l, q)$$

Consumer chooses trips (*x*) and leisure time (*l*), with implied money left over (*z*)

Theoretical model (cont.)

First order conditions:

[*x*] $U_x - pU_z = 0 \quad \rightarrow \quad \frac{U_x}{U_z} = p$

[*l*] $-wU_z + U_l = 0 \quad \rightarrow \quad \frac{U_l}{U_z} = w$

$\boldsymbol{\frac{U_x}{U_z} = p}$ implies that the consumer sets their marginal rate of substitution between recreational trips and numeraire consumption equal to the full travel cost of the trip! **Therefore, the value of the consumer's marginal trip is equal to the travel cost.**

Theoretical model (cont.)

If we know the functional form of *U(.)*, we can use the FOCs to solve for *x* as a function of the model's parameters (*p, Y, q*):

$$\boldsymbol{x = f(p, Y, q)}$$

This is just a demand curve for trips (as a function of travel cost, full budget, and site quality).

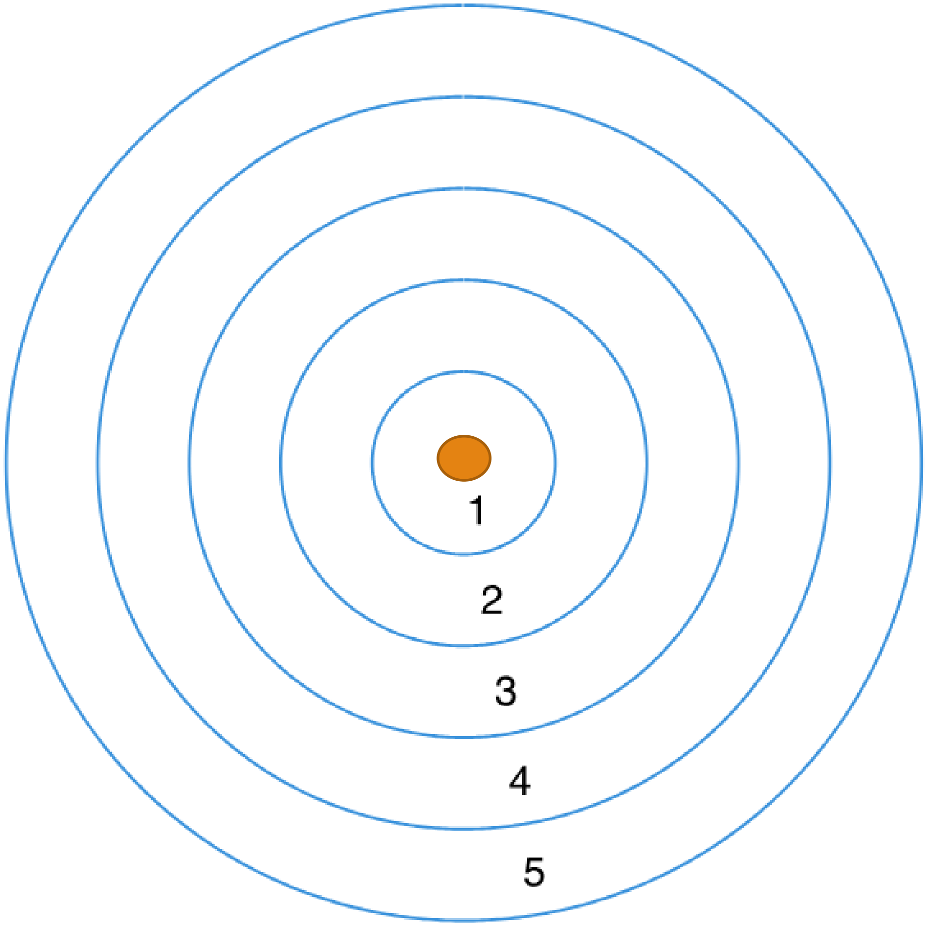
If we observe consumers going to sites of different travel costs, we are moving up and down the demand curve. Thus, we can trace out the curve (and compute consumer surplus!)

A stylized empirical version of the model

- Travel cost model for a single recreational site.
- Construct 5 zones as concentric circles around the site
  - Assume travel costs for residents of each zone to the site are identical
- Perform a survey to assess the total count of per-capita visits for residents of each zone (x_i)
- Construct a travel cost measure, based on round-trip costs of transportation and consumer time (i.e. foregone wages), and an entry fee (tc_i)
- Collect sociodemographic information about residents in your survey (s_i)
- Estimate the model, assuming some structure on the demand function (*g(.)*)

$$x_i = g(tc_i, s_i) + \varepsilon_i$$

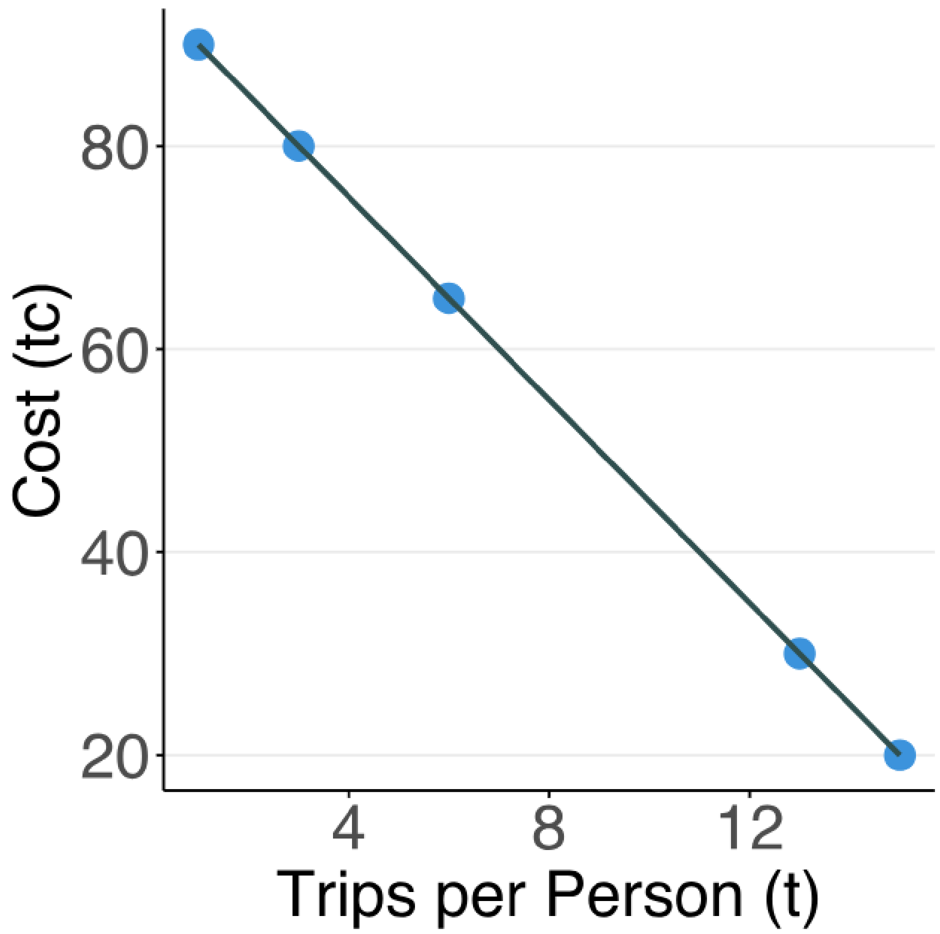
A stylized empirical version of the model



Suppose our survey returns data of the following nature:

```
## # A tibble: 5 × 5
##   zone   dist   pop  cost   vpp
##   <chr> <dbl> <dbl> <dbl> <dbl>
## 1 A         2 10000    20    15
## 2 B        30 10000    30    13
## 3 C        90 20000    65     6
## 4 D       140 10000    80     3
## 5 E       150 10000    90     1
```

A stylized empirical version of the model

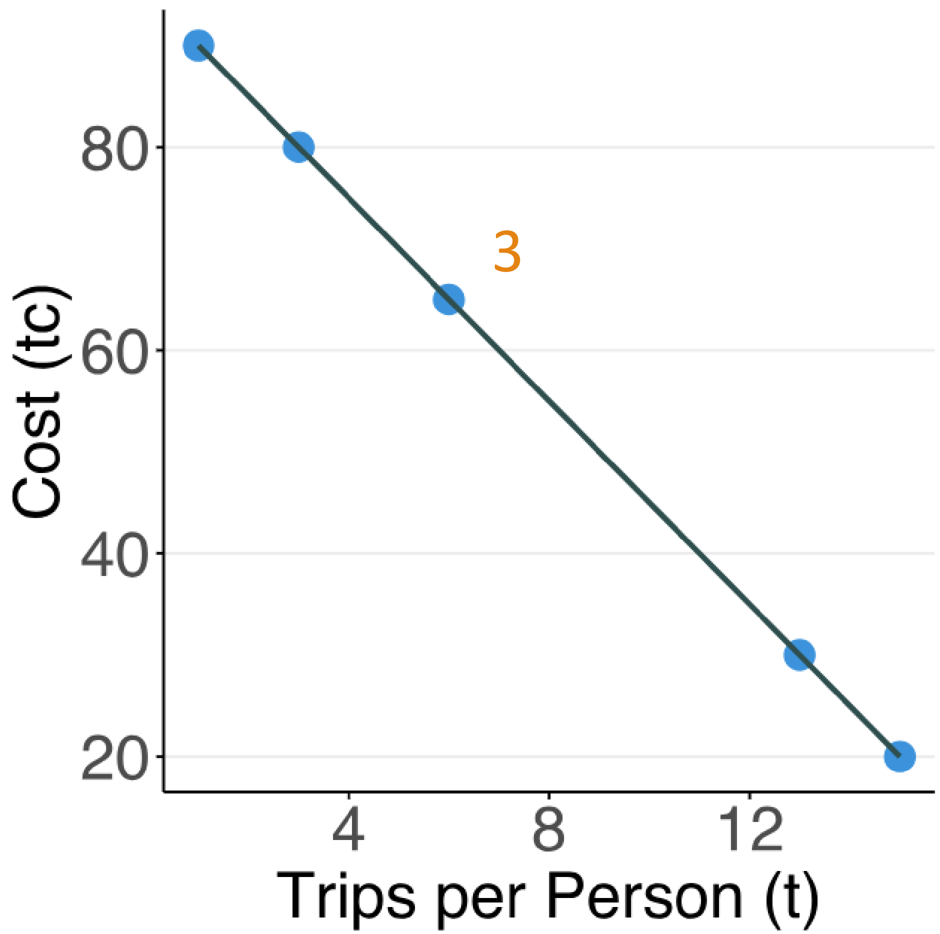


Using our stylized data, we can fit a linear curve for *g(.)* of the form:

$$x_i = \beta_0 + \beta_1 tc_i$$

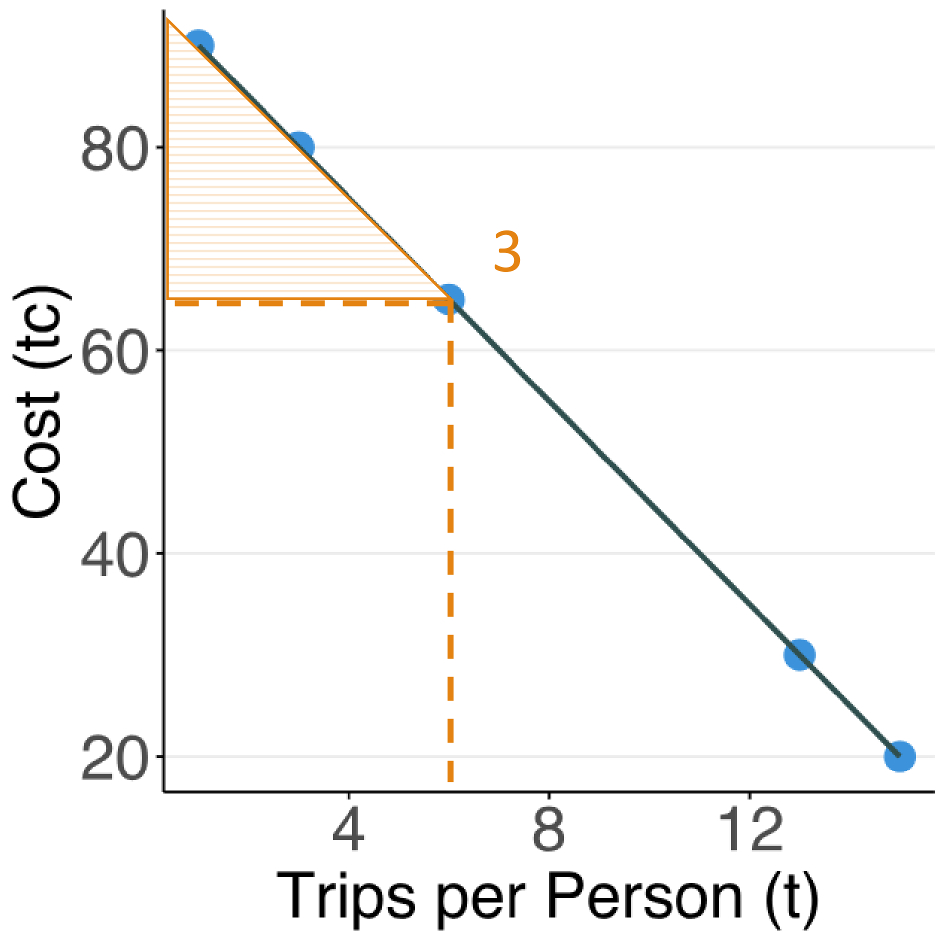
```
## # A tibble: 5 × 5
##   zone   dist   pop  cost   vpp
##   <chr> <dbl> <dbl> <dbl> <dbl>
## 1 A         2 10000    20    15
## 2 B        30 10000    30    13
## 3 C        90 20000    65     6
## 4 D       140 10000    80     3
## 5 E       150 10000    90     1
```

A stylized empirical version of the model



What is the net benefit of this recreational site for residents of zone 3?

A stylized empirical version of the model



What is the net benefit of this recreational site for residents of zone 3?

For a given person from zone 3, per capita consumer surplus is given by integrating under the demand curve and netting out total visit costs.

In this stylized example, with linear demand, that's given by the area of the orange triangle:

CS = 0.5 * 6 * (95-65) = $90

For 20,000 residents, the total net benefit is therefore $1.8 mil.

Multi-site Travel Cost Model

- With a single site model, we can say something about the total value of the site. **But what about the value of a site's individual attributes?**

Extending the Travel Cost Model

- With a single site model, we can say something about the total value of the site. But what about the value of a site's individual attributes?

- In a single site model, there is no variation in attributes!

- To value individual attributes and answer questions similar to the following, we need to estimate a multi-site model:

  - What is value of the site's rock climbing walls?
  - What is benefit of a program to restock a park's lakes with walleye?
  - What is recreational loss to deer hunters from chronic wasting disease?

Multi-site Travel Cost Model

$$\mathrm{V_{ijt}} \quad = \quad \lambda tc_{ijt} \; + \quad \beta X \qquad + \quad \phi \quad + \quad \varepsilon_{ijt}$$

Multi-site Travel Cost Model

$$\mathrm{V}_{\mathrm{ijt}} = \lambda tc_{ijt} + \beta X + \phi + \varepsilon_{ijt}$$

= $$$   + + +

Multi-site Travel Cost Model

$$V_{ijt} = \lambda tc_{ijt} + \beta X + \phi + \varepsilon_{ijt}$$

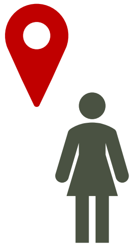
=

+

+ +

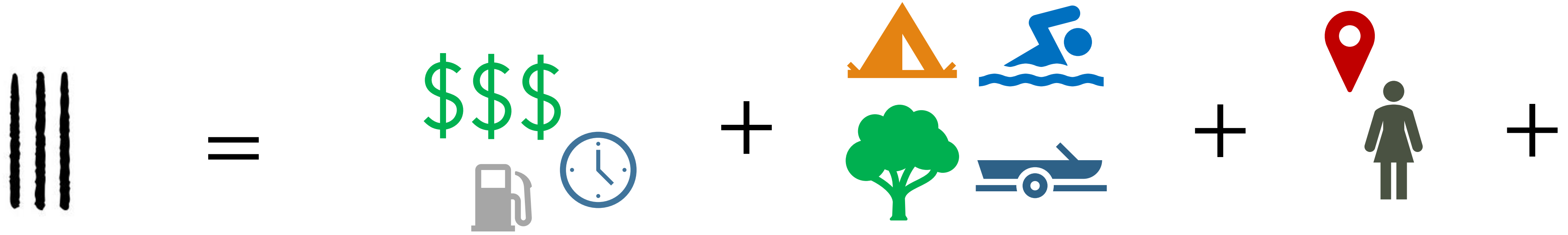
Multi-site Travel Cost Model

$$V_{ijt} = \lambda tc_{ijt} + \beta X + \phi + \varepsilon_{ijt}$$

= $$$  +  +  +

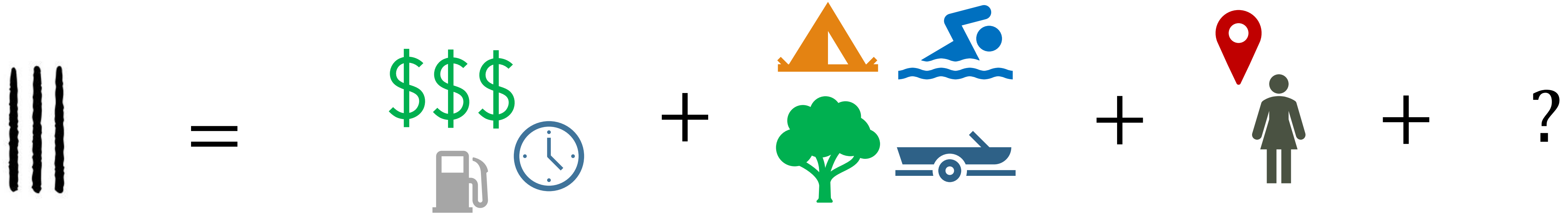
Multi-site Travel Cost Model

$$V_{\mathrm{ijt}} = \lambda tc_{ijt} + \beta X + \phi + \varepsilon_{ijt}$$



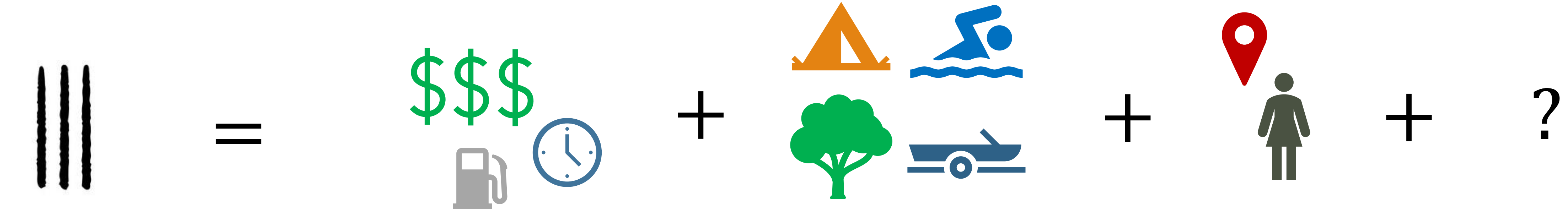
Multi-site Travel Cost Model

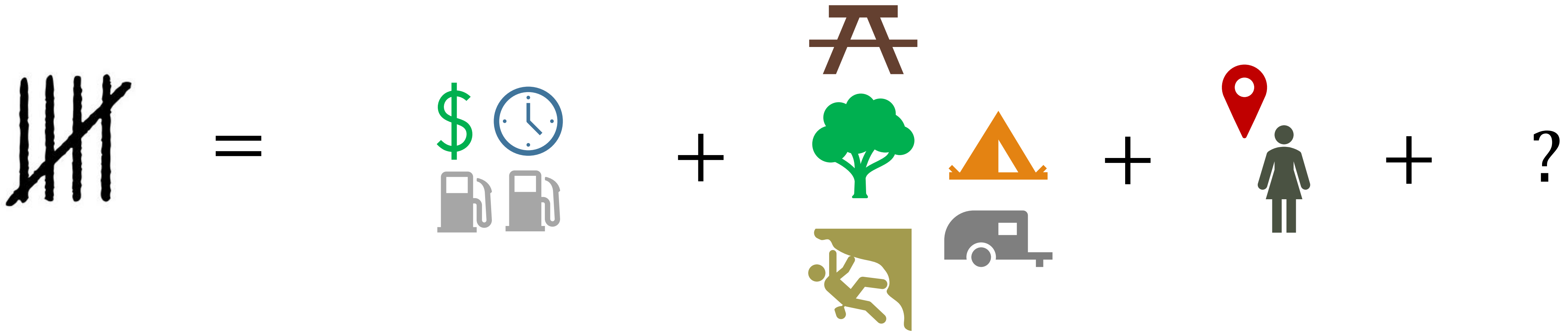
$$\mathrm{V}_{\mathrm{ijt}} = \lambda tc_{ijt} + \beta X + \phi + \varepsilon_{ijt}$$



Multi-site Travel Cost Model

$$V_{ijt} \quad = \quad \lambda tc_{ijt} \quad + \quad \beta X \quad + \quad \phi \quad + \quad \varepsilon_{ijt}$$





Multi-site Travel Cost Model

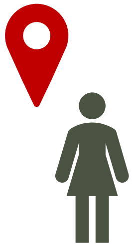
$$V_{\text{ijt}} = \lambda tc_{ijt} + \beta X + \phi + \varepsilon_{ijt}$$


i=1, j=1, t=1

=

+

+



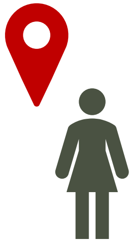
+ ?


i=1, j=2, t=1

=

+

+



+ ?

Multi-site Travel Cost Model

$$V_{\mathrm{ijt}} = \lambda tc_{ijt} + \beta X + \phi + \varepsilon_{ijt}$$

$-0.05 \times$ \$ \$ \$  

$+$

$1.5 \times$ 

$2.5 \times$ 

$1.8 \times$ 

$0.5 \times$ 

$0.7 \times$ 

$0.6 \times$ 

$0.3 \times$ 

$+$

$35.1 \times$ 

$15.2 \times$ 

Multi-site Travel Cost Model

To restrict demand > 0, typically add nonlinear, count data structure via logistic, Poisson, or negative binomial distributional assumptions. With this structure, we estimate MWTP to pay for an attribute, *n,* as a ratio of marginal utility parameters:

$$\widehat{MWTP}_n = \frac{\beta_n}{-\lambda}$$

Access value / consumer surplus for a given site(s) depends on the model approach:

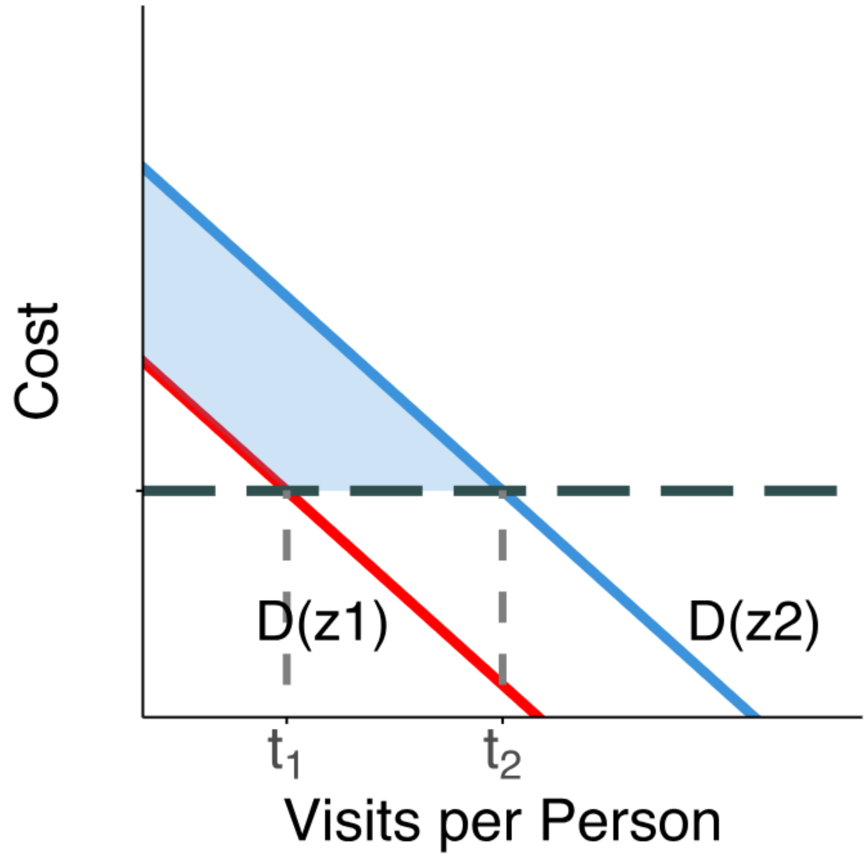
$$\text{[Poisson, NB]} \qquad \widehat{CS_{ijt}} = \frac{\exp(\widehat{V_{ijt}})}{-\lambda}$$

$$\text{[RUM]} \qquad \widehat{CS_{it}} = \frac{\ln\left(\sum_{j=1}^{J} \exp(\widehat{V_{ijt}})\right)}{-\lambda}$$

Ch. 9 of Champ et al for derivations + more, if curious.

Multi-site Travel Cost Model

- Final point: given the demand curve parameters we've estimated, we can explore how demand shifts with a change in a site's quality!
- If we improve a quality characteristic, *z*, and make the corresponding change on graph at right, observe shift in demand from D(z1) to D(z2).
- Gain in consumer surplus? Area shaded in blue.



Travel Cost Modelling: Issues

- Economists have explored best practices related to several issues that arise when implementing a TC model, including:
  - How to measure the travel cost? Especially opportunity cost of time…
  - How to select sites and set recreational boundaries for inclusion in the study?
  - How to collect a study sample?
  - How to treat multi-purpose trips? Multi-day, multi-activity trips?
  - Best functional form for demand curve?

Valuing urban open space using the travel-cost method and the implications of measurement error (here)

By: Hanauer and Reid (2017)

- Research Questions:

  1. What is the value of Taylor Mountain Regional Park in Santa Rosa, California?

  2. Can using individual-specific travel cost estimates improve estimation?

Valuing urban open space using the travel-cost method and the implications of measurement error (here)

By: Hanauer and Reid (2017)

- Research Questions:

1. What is the value of Taylor Mountain Regional Park in Santa Rosa, California?
    - On average, $13.70 per trip, or $1.5mil each year

2. Can using individual-specific travel cost estimates improve estimation?
    - They find evidence that using conventional methods could potentially understate the value of the regional park.

Valuing urban open space using the travel-cost method and the implications of measurement error (here)

By: Hanauer and Reid (2017)

- Data:

  1. 439 intercept surveys
     - Number of trips, costs, home address, how they got there, if they paid for parking, activities they participate in, income, demographics, etc.
     - Average number of self reported trips in the past year 32.8
     - 72% white, $80k income

  2. How were costs calculated?

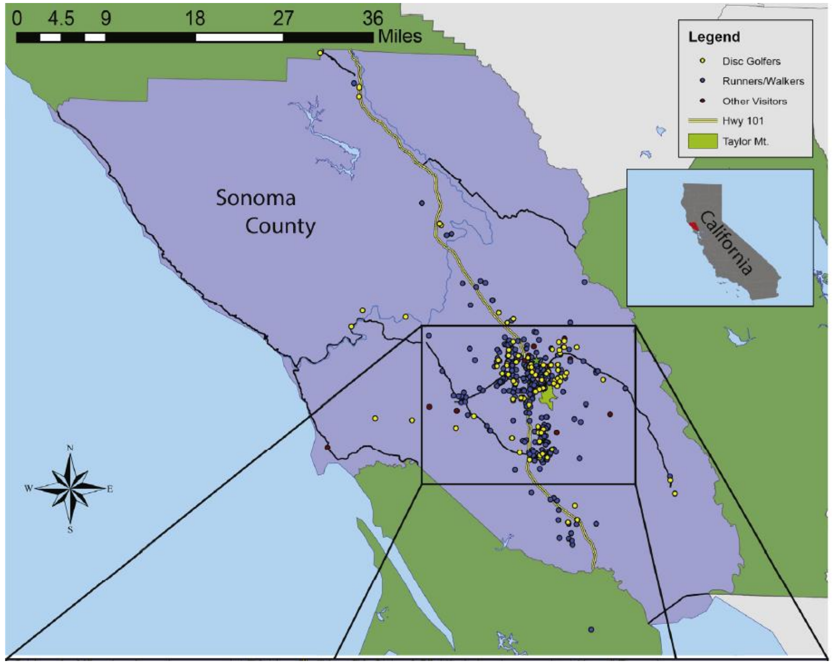
Valuing urban open space using the travel-cost method and the implications of measurement error (here)

By: Hanauer and Reid (2017)

- Data:

1. 439 intercept surveys
    - Number of trips, costs, home address, how they got there, if they paid for parking, activities they participate in, income, demographics, etc.
    - Average number of self reported trips in the past year 32.8
    - 72% white, $80k income

2. How were costs calculated?
    - $Trip\ Cost = \frac{1}{3} wage \times hours + vehicle\ costs + parking\ fees$
    - Average trip cost was $24



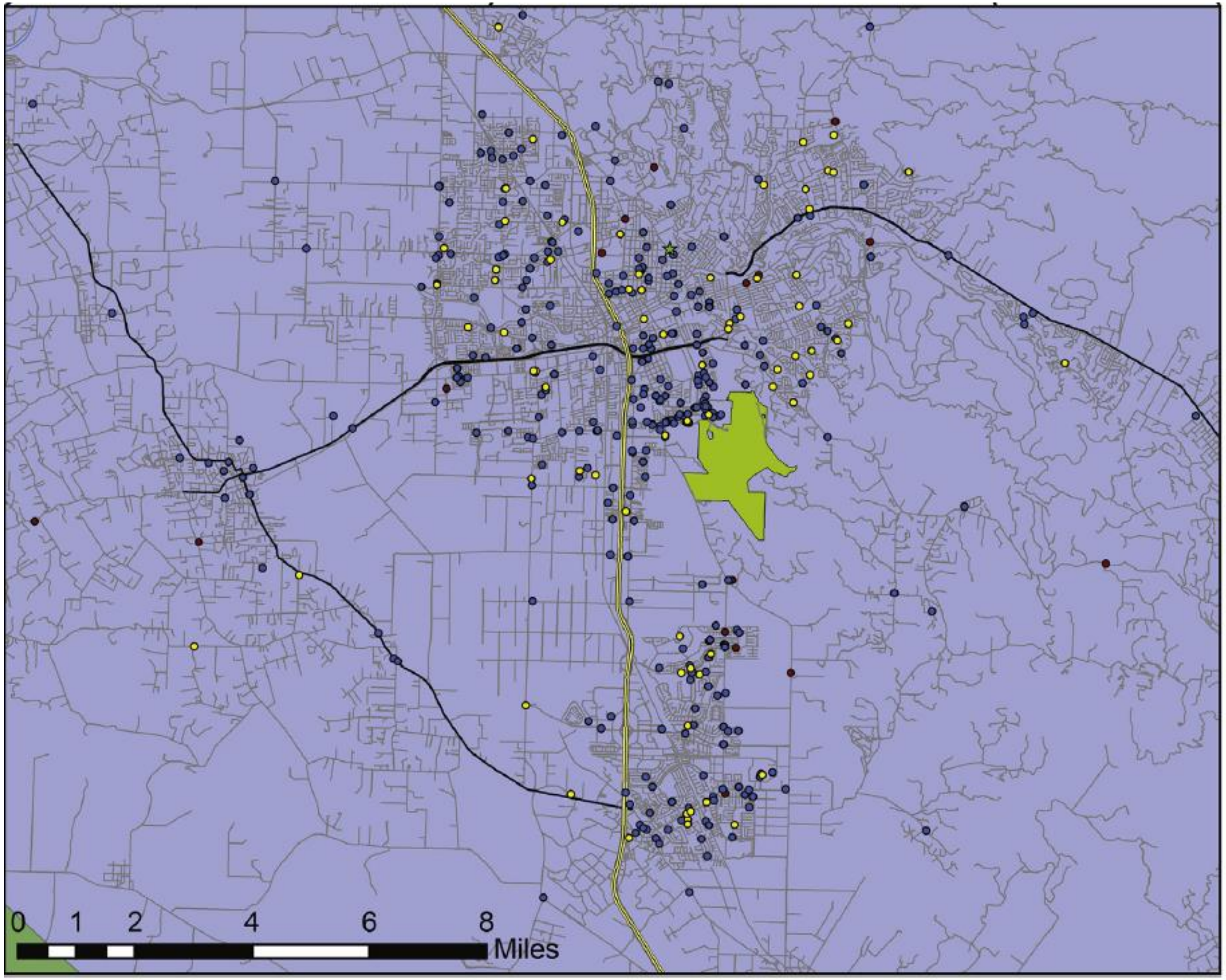


Fig. 1. Locations of Taylor Mountain Regional Park and households of visitors in the sample.

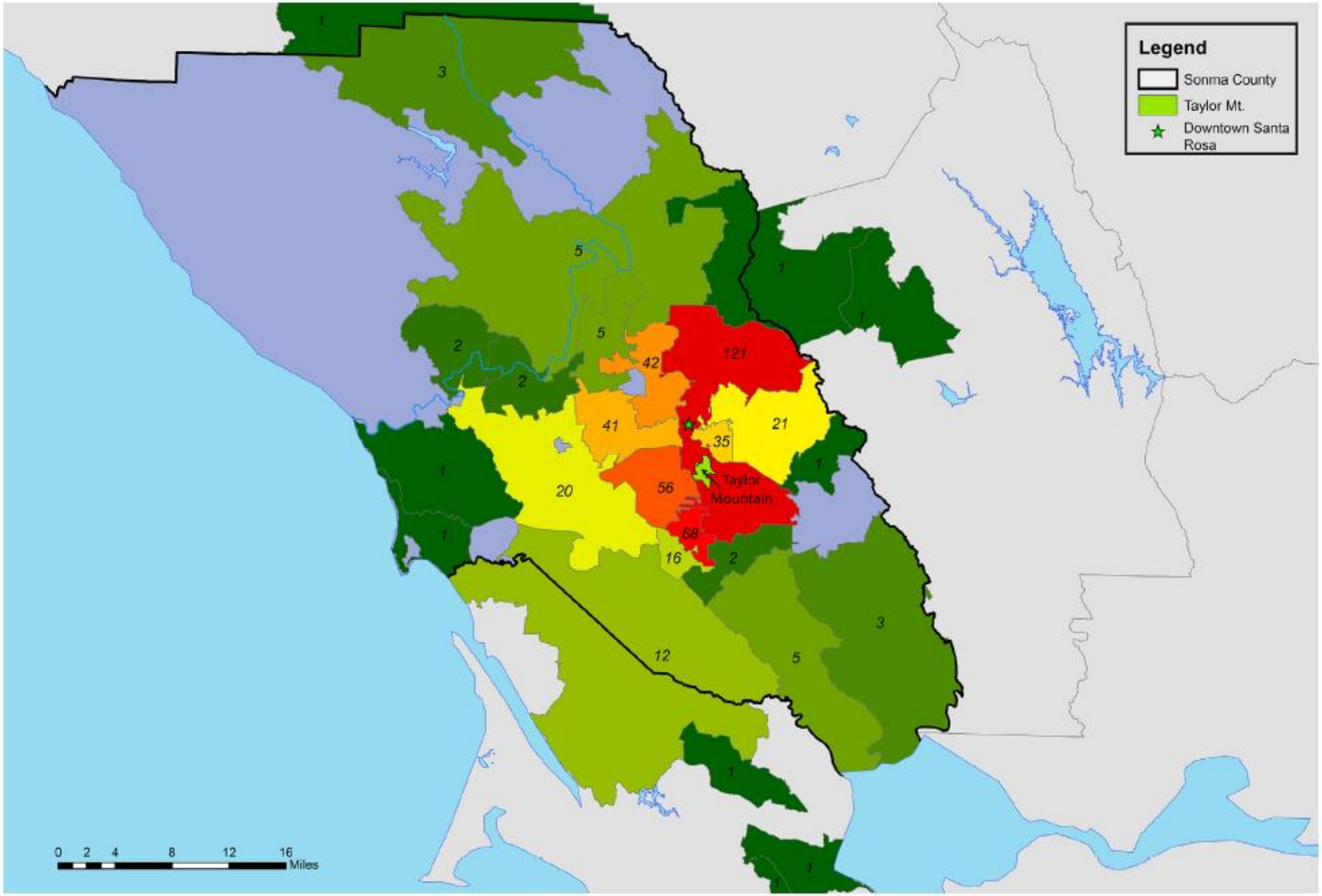


Fig. 2. Visitors' household location according to zip-code boundaries. The numbers represent the number of visitors within the sample that originated from the respective zip code.

$$V_{ij} = \sum_{j=1}^{j=3} \lambda_j cost_{ij} + \sum_{k=1}^{K} \beta_k x_{ik} + \varepsilon_{ij}$$

Table 2

Regression results from our primary measurement specification. Columns 1–3 present results from poisson regressions with various control variable specifications. Columns 4–6 present results from negative binomial regressions with various control variable specifications. All regressions account for zero truncation and endogenous stratification.

Dependent Variable: Number of Visits in Past Year						
Variables	Poisson			Truncated Negative Binomial		
	(1)	(2)	(3)	(4)	(5)	(6)
Travel Cost TM	-0.0329^{***}	-0.0626^{***}	-0.0630^{***}	-0.0300^{***}	-0.0697^{***}	-0.0730^{***}
	(0.000736)	(0.00117)	(0.00122)	(0.00227)	(0.00441)	(0.00463)
Travel Cost Annadel		0.0207^{***}	0.0174^{***}		0.0412^{***}	0.0391^{***}
		(0.00114)	(0.00119)		(0.00559)	(0.00585)
Travel Cost Crane Creek		−0.000513	0.00193^{***}		0.00450	0.00515
		(0.000608)	(0.000637)		(0.00385)	(0.00371)
Income (1000s)		0.00481^{***}	0.00419^{***}		0.00168	0.00239^{**}
		(0.000204)	(0.000214)		(0.00105)	(0.00121)
Constant	4.049^{***}	3.661^{***}	3.399^{***}	-11.21^{***}	−8.358	−10.52
	(0.0137)	(0.0170)	(0.0456)	(0.0683)	(26.94)	(76.89)
Additional Controls			Yes			Yes
Observations	439	439	439	439	439	439
AIC	24887.15	22152.69	20810.14	3801.91	3638.09	3588.79
Alpha				1.62^{***}	1.41^{***}	1.30^{***}

Standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

$$V_{ijt} = \sum_{j=1}^{j=3} \lambda_j cost_{ijt} + \sum_{k=1}^{K} \beta_k x_{ikt}^{k} + \varepsilon_{ijt}$$

Table 2

Regression results from our primary measurement specification. Columns 1–3 present results from poisson regressions with various control variable specifications. Columns 4–6 present results from negative binomial regressions with various control variable specifications. All regressions account for zero truncation and endogenous stratification.

Dependent Variable: Number of Visits in Past Year						
Variables	Poisson			Truncated Negative Binomial		
	(1)	(2)	(3)	(4)	(5)	(6)
Travel Cost TM	−0.0329***	−0.0626***	−0.0630***	−0.0300***	−0.0697***	−0.0730***
	(0.000736)	(0.00117)	(0.00122)	(0.00227)	(0.00441)	(0.00463)
Travel Cost Annadel		0.0207***	0.0174***		0.0412***	0.0391***
		(0.00114)	(0.00119)		(0.00559)	(0.00585)
Travel Cost Crane Creek		−0.000513	0.00193***		0.00450	0.00515
		(0.000608)	(0.000637)		(0.00385)	(0.00371)
Income (1000s)		0.00481***	0.00419***		0.00168	0.00239**
		(0.000204)	(0.000214)		(0.00105)	(0.00121)
Constant	4.049***	3.661***	3.399***	−11.21***	−8.358	−10.52
	(0.0137)	(0.0170)	(0.0456)	(0.0683)	(26.94)	(76.89)
Additional Controls			Yes			Yes
Observations	439	439	439	439	439	439
AIC	24887.15	22152.69	20810.14	3801.91	3638.09	3588.79
Alpha				1.62***	1.41***	1.30***

Standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

$$V_{ijt} = \sum_{j=1}^{j=3} \lambda_j cost_{ijt} + \sum_{k=1}^{K} \beta_k x_{ikt}^{k} + \varepsilon_{ijt}$$

Table 2

Regression results from our primary measurement specification. Columns 1–3 present results from poisson regressions with various control variable specifications. Columns 4–6 present results from negative binomial regressions with various control variable specifications. All regressions account for zero truncation and endogenous stratification.

Dependent Variable: Number of Visits in Past Year						
Variables	Poisson			Truncated Negative Binomial		
	(1)	(2)	(3)	(4)	(5)	(6)
Travel Cost TM	−0.0329***	−0.0626***	−0.0630***	−0.0300***	−0.0697***	−0.0730***
	(0.000736)	(0.00117)	(0.00122)	(0.00227)	(0.00441)	(0.00463)
Travel Cost Annadel		0.0207***	0.0174***		0.0412***	0.0391***
		(0.00114)	(0.00119)		(0.00559)	(0.00585)
Travel Cost Crane Creek		−0.000513	0.00193***		0.00450	0.00515
		(0.000608)	(0.000637)		(0.00385)	(0.00371)
Income (1000s)		0.00481***	0.00419***		0.00168	0.00239**
		(0.000204)	(0.000214)		(0.00105)	(0.00121)
Constant	4.049***	3.661***	3.399***	−11.21***	−8.358	−10.52
	(0.0137)	(0.0170)	(0.0456)	(0.0683)	(26.94)	(76.89)
Additional Controls			Yes			Yes
Observations	439	439	439	439	439	439
AIC	24887.15	22152.69	20810.14	3801.91	3638.09	3588.79
Alpha				1.62***	1.41***	1.30***

Standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

$$V_{ijt} = \sum_{j=1}^{j=3} \lambda_j cost_{ijt} + \sum_{k=1}^{K} \beta_k x_{ikt}^{k} + \varepsilon_{ijt}$$

Table 2
Regression results from our primary measurement specification. Columns 1–3 present results from poisson regressions with various control variable specifications. Columns 4–6 present results from negative binomial regressions with various control variable specifications. All regressions account for zero truncation and endogenous stratification.

Dependent Variable: Number of Visits in Past Year						
Variables	Poisson			Truncated Negative Binomial		
	(1)	(2)	(3)	(4)	(5)	(6)
Travel Cost TM	−0.0329***	−0.0626***	−0.0630***	−0.0300***	−0.0697***	−0.0730***
	(0.000736)	(0.00117)	(0.00122)	(0.00227)	(0.00441)	(0.00463)
Travel Cost Annadel		0.0207***	0.0174***		0.0412***	0.0391***
		(0.00114)	(0.00119)		(0.00559)	(0.00585)
Travel Cost Crane Creek		−0.000513	0.00193***		0.00450	0.00515
		(0.000608)	(0.000637)		(0.00385)	(0.00371)
Income (1000s)		0.00481***	0.00419***		0.00168	0.00239**
		(0.000204)	(0.000214)		(0.00105)	(0.00121)
Constant	4.049***	3.661***	3.399***	−11.21***	−8.358	−10.52
	(0.0137)	(0.0170)	(0.0456)	(0.0683)	(26.94)	(76.89)
Additional Controls			Yes			Yes
Observations	439	439	439	439	439	439
AIC	24887.15	22152.69	20810.14	3801.91	3638.09	3588.79
Alpha				1.62***	1.41***	1.30***

Standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

$$V_{ijt} = \sum_{j=1}^{j=3} \lambda_j cost_{ijt} + \sum_{k=1}^{K} \beta_k x_{ikt}^{k} + \varepsilon_{ijt}$$

Table 2

Regression results from our primary measurement specification. Columns 1–3 present results from poisson regressions with various control variable specifications. Columns 4–6 present results from negative binomial regressions with various control variable specifications. All regressions account for zero truncation and endogenous stratification.

Dependent Variable: Number of Visits in Past Year						
Variables	Poisson			Truncated Negative Binomial		
	(1)	(2)	(3)	(4)	(5)	(6)
Travel Cost TM	−0.0329***	−0.0626***	−0.0630***	−0.0300***	−0.0697***	−0.0730***
	(0.000736)	(0.00117)	(0.00122)	(0.00227)	(0.00441)	(0.00463)
Travel Cost Annadel		0.0207***	0.0174***		0.0412***	0.0391***
		(0.00114)	(0.00119)		(0.00559)	(0.00585)
Travel Cost Crane Creek		−0.000513	0.00193***		0.00450	0.00515
		(0.000608)	(0.000637)		(0.00385)	(0.00371)
Income (1000s)		0.00481***	0.00419***		0.00168	0.00239**
		(0.000204)	(0.000214)		(0.00105)	(0.00121)
Constant	4.049***	3.661***	3.399***	−11.21***	−8.358	−10.52
	(0.0137)	(0.0170)	(0.0456)	(0.0683)	(26.94)	(76.89)
Additional Controls			Yes			Yes
Observations	439	439	439	439	439	439
AIC	24887.15	22152.69	20810.14	3801.91	3638.09	3588.79
Alpha				1.62***	1.41***	1.30***

Standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

$$V_{ijt} = \sum_{j=1}^{j=3} \lambda_j cost_{ijt} + \sum_{k=1}^{K} \beta_k x_{ikt}^k + \varepsilon_{ijt}$$

Table 2

Regression results from our primary measurement specification. Columns 1–3 present results from poisson regressions with various control variable specifications. Columns 4–6 present results from negative binomial regressions with various control variable specifications. All regressions account for zero truncation and endogenous stratification.

Dependent Variable: Number of Visits in Past Year						
Variables	Poisson			Truncated Negative Binomial		
	(1)	(2)	(3)	(4)	(5)	(6)
Travel Cost TM	−0.0329***	−0.0626***	−0.0630***	−0.0300***	−0.0697***	−0.0730***
	(0.000736)	(0.00117)	(0.00122)	(0.00227)	(0.00441)	(0.00463)
Travel Cost Annadel		0.0207***	0.0174***		0.0412***	0.0391***
		(0.00114)	(0.00119)		(0.00559)	(0.00585)
Travel Cost Crane Creek		−0.000513	0.00193***		0.00450	0.00515
		(0.000608)	(0.000637)		(0.00385)	(0.00371)
Income (1000s)		0.00481***	0.00419***		0.00168	0.00239**
		(0.000204)	(0.000214)		(0.00105)	(0.00121)
Constant	4.049***	3.661***	3.399***	−11.21***	−8.358	−10.52
	(0.0137)	(0.0170)	(0.0456)	(0.0683)	(26.94)	(76.89)
Additional Controls			Yes			Yes
Observations	439	439	439	439	439	439
AIC	24887.15	22152.69	20810.14	3801.91	3638.09	3588.79
Alpha				1.62***	1.41***	1.30***

Standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

$$\overline{CS} = \frac{1}{\lambda}$$

Table 3
Consumer surplus calculations based on primary specification.

	Point Estimate	95% Confidence Interval	
		Lower	Upper
Mean CS_i/visit	$\boxed{\$13.70}$	\$12.17	\$15.65
Total CS/year	\$1,480,782.42	\$1,315,410.37	\$1,691,550.73
Discount Rate	Present Value of Future Benefits		
1%	\$148,078,242.44	\$131,541,037.26	\$169,155,072.56
3%	\$49,359,414.15	\$43,847,012.42	\$56,385,024.19
5%	\$29,615,648.49	\$26,308,207.45	\$33,831,014.51

$$\overline{CS} = \frac{1}{\lambda}$$

Table 3
Consumer surplus calculations based on primary specification.

	Point Estimate	95% Confidence Interval	
		Lower	Upper
Mean CS_i/visit	$13.70	$12.17	$15.65
Total CS/year	$\boxed{\$1{,}480{,}782.42}$	$\$1{,}315{,}410.37$	$\$1{,}691{,}550.73$
Discount Rate	Present Value of Future Benefits		
1%	$148,078,242.44	$131,541,037.26	$169,155,072.56
3%	$49,359,414.15	$43,847,012.42	$56,385,024.19
5%	$29,615,648.49	$26,308,207.45	$33,831,014.51

$$\overline{CS} = \frac{1}{\lambda}$$

Table 3
Consumer surplus calculations based on primary specification.

	Point Estimate	95% Confidence Interval	
		Lower	Upper
Mean CS_i/visit	$13.70	$12.17	$15.65
Total CS/year	$1,480,782.42	$1,315,410.37	$1,691,550.73
Discount Rate	Present Value of Future Benefits		
1%	$148,078,242.44	$131,541,037.26	$169,155,072.56
3%	$49,359,414.15	$43,847,012.42	$56,385,024.19
5%	$29,615,648.49	$26,308,207.45	$33,831,014.51

- Does using zip-code level data to estimate travel costs bias the results?
  - The authors find that by failing to account for within-zip-code variation in travel costs the per trip consumer surplus and, thus, the overall benefits of Taylor Mountain Regional Park are underestimated compared to when more accurate individual-level costs are used.

Table 4
Comparison of primary results (bottom row) to results based on zip code point of origin. Each of the first six rows presents distribution of travel time estimates (columns 2–5), regression results (for the primary coefficient on travel cost to Taylor Mountain, column 7), estimated per-trip consumer surplus (column 8), and a comparison to the primary consumer surplus estimates (column 9), based on different assumptions on average travel speed for the linear zip code specification. The seventh row presents the same information for the route-based zip code specification.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Average MPH	Distribution of Travel Time Calculations (minutes)					Primary Coeff.	Mean CS_i/visit	Percent Diff.
	Mean	Median	SD	Min	Max			
55	5.67	3.56	5.02	1.34	45.4	−0.1364	$7.33	46.51%
45	6.93	4.35	6.14	1.64	55.49	−0.1349	$7.42	45.88%
35	8.91	5.59	7.89	2.1	71.34	−0.1321	$7.57	44.74%
25	12.47	7.83	11.05	2.94	99.88	−0.1262	$7.92	42.18%
15	20.79	13.04	18.42	4.9	166.47	−0.1104	$9.06	33.89%
10	31.18	19.57	27.63	7.36	249.7	−0.0910	$10.98	19.83%
Route-Based	28.94	17.58	30.9	10.8	122.3	−0.1154	$8.67	36.74%
Primary	17.71	14.75	9.75	3.37	56.58	−0.0730	$13.70	–

Next class

- Hedonics:
  - Two papers:
    1. [Muehlenbachs et al. (2015)]
    2. [Christensen and Timmins (2023)]: (read the intro. For those interested in causal inference, also read Sec 3.)

- Case Study #1 due Sept 17th by 11:59pm
  - Estimate a travel cost model.
  - Data and code are provided! You will run the script, get acquainted with the R environment, and provide some analysis of the results.
  - Your job will be to submit a writeup and code (using the provided R markdown template), explain the intuition, any potentially missing information/data that you would have like to have included in the analysis.