3. Transportation demand

The discrete good case

3.1. Theory

Introduction

- Some transportation choices are inherently discrete (either – or choice)
- In this lecture we extend the theory of consumption to explicitly consider goods which have an either – or character

Intensive and extensive margin

- When the good demanded is continuous, changes in the economic environment occur at the intensive margin = individuals consume a little more or less of the good when prices or income change.
- When the good is discrete, consumers respond to changes in their economic environments by switching from one alternative to another, a demand response which is said to occur at the extensive margin.

Discrete alternatives

T_a = 1 if automobile is taken; = 0 if bus is taken
T_b = 1 if bus is taken; = 0 if automobile is taken

$$??_{a}^{*} = ??_{a}\left(??_{??a}, ??_{??b}, ??_{??}, ??; ??\right)$$

$$??_{b}^{*} = ??_{b}\left(??_{??a}, ??_{??b}, ??_{??}, ??; ??\right)$$

$$??^{*} = ??\left(??_{??a}, ??_{??b}, ??_{??}, ??; ??\right)$$

when it is recognized that T_a* a T_b* are mutually exclusive

Indirect utility function

$$\square\left(\square_a^*, \square_b^*, \square^*; \square\right) =$$

$$= \square\Big(\square_a\big(\square_{\square a}, \square_{\square b}, \square_{\square}, \square; \square\big), \square_b\big(\square_{\square a}, \square_{\square b}, \square_{\square}, \square; \square\big), \square\big(\square_{\square a}, \square_{\square b}, \square_{\square}, \square; \square\big); \square\Big)$$

$$= \widehat{\square}\left(\square_{\square a}, \square_{\square b}, \square_{\square}, \square; \square\right)$$

- U is called a direct utility function, which consumer maximizes subject to budget constraint.
- Û is called an indirect utility function, wchich gives the maximum utility that a consumer can achieve for a particular economic enviroment as defined by one’s income and the existing level of prices.

Conditional indirect utility function

Let $\hat{U}_i\,(p_{Ti}, p_x, Y, \phi)$ be the conditional indirect utility function for choice i (i = a,b). Since this indirect utility is conditional upon a particular choice i, only the price of that alternative p_{Ti} is included as an argument in the function.

If the conditional indirect utility for the automobile mode is greater than that of the bus mode, then the consumer will take an automobile to work. Specifically, the auto is selected for the work trip if:

$$\hat{U}_a\,(p_{Ta}, p_x, Y, \phi) > \hat{U}_b\,(p_{Tb}, p_x, Y, \phi)$$

Market demand and consumption at the extensive margin

- To develop a market demand model for work trip mode choice, suppose that we adopt the same assumptions as in the divisible choice models
- Since all individuals are identical, economic theory predicts, that each individual selects the same mode in the trip to work. The market demand for one of the modes will be zero! Something is wrong!
- The assumption that all consumers have identical preferences is implausible and for discrete goods case we need to explicitly incorporate variation in taste across population.

Observed and unobserved utility

Assume that each individual's indirect utility function for the automobile and bus alternatives is given by:

$$\hat{U}_{\mathrm{a}} = Y - p_x + V_{\mathrm{a}}(p_{T\mathrm{a}}, Y; \phi) + \varepsilon_{\mathrm{a}}$$
$$\hat{U}_{\mathrm{b}} = Y - p_x + V_{\mathrm{b}}(p_{T\mathrm{b}}, Y; \phi) + \varepsilon_{\mathrm{b}}$$

- where V_i (i=a,b) is an observable empirical function and $(Y - p_x - V_i)$ is that portion of consumer's conditional indirect utility which is observable and common across all individuals in the population. It reflects „representative“ or average tastes in the population.
- $\varepsilon_{i,}$ on the other hand is unobservable and individual specific

In general, identical observed portions of indirect utility do not imply identical total indirect utility levels and thus do not necessarily imply identical choice behavior.

Random utility model

- Since each consumer's utility depends upon an unobserved individual specific term, ε_i which is assumed to randomly vary from one individual to another, indirect utility also varies randomly from one individual to another.
- The fact that we cannot observe ε for any individual implies that his choice cannot be predicted with certainty, but only probabilistically.
- Thus, for an individual randomly selected, the probability that he chooses and automobile is:

$$P_{\mathrm{a}} = \Pr\left(\hat{U}_{\mathrm{a}}(p_{T\mathrm{a}}, p_x, Y; \phi) > \hat{U}_{\mathrm{b}}(p_{T\mathrm{b}}, p_x, Y; \phi)\right)$$

$$\Rightarrow P_{\mathrm{a}} = \Pr(p_{\mathrm{x}} + V_{\mathrm{a}}(p_{T\mathrm{a}}, Y; \phi) + \varepsilon_{\mathrm{a}} > p_{\mathrm{x}} + V_{\mathrm{b}}(p_{T\mathrm{b}}, Y; \phi) + \varepsilon_{\mathrm{b}})$$

$$= \Pr\left(\varepsilon_{\mathrm{b}} - \varepsilon_{\mathrm{a}} < V_{\mathrm{a}}(p_{T\mathrm{a}}, Y; \phi) - V_{\mathrm{b}}(p_{T\mathrm{b}}, Y; \phi)\right)$$

Distribution function

A distribution function gives the probability that a random variable takes on a value which is less than or equal to a given value of x. If X is a random variable, the distribution function of X evaluated at point x is:

$$F(x) = Pr\ (X \leq x)$$

Which is the probability that X is less or equal to a specific value x. Since the distribution function is a probabilioty, its value lies between zero and one.

Probabilistic choice models

Replacing the random variable X with $\varepsilon_b - \varepsilon_a$ and x with $V_a - V_b$ in distribution function gives the random utility model. In the other words, the probability function is a cumulative distribution function and the random utility model represents a probability model of transportation choice.

Specifically:

$$\square\square\square = \Pr\left(\square_b - \square_a < \square_a(\square_{\square a}, \square; \square) - \square_b(\square_{\square b}, \square; \square)\right)$$

$$= F(V_a(p_{Ta}; Y; \square) - V_b(p_{Tb}; Y; \square))$$

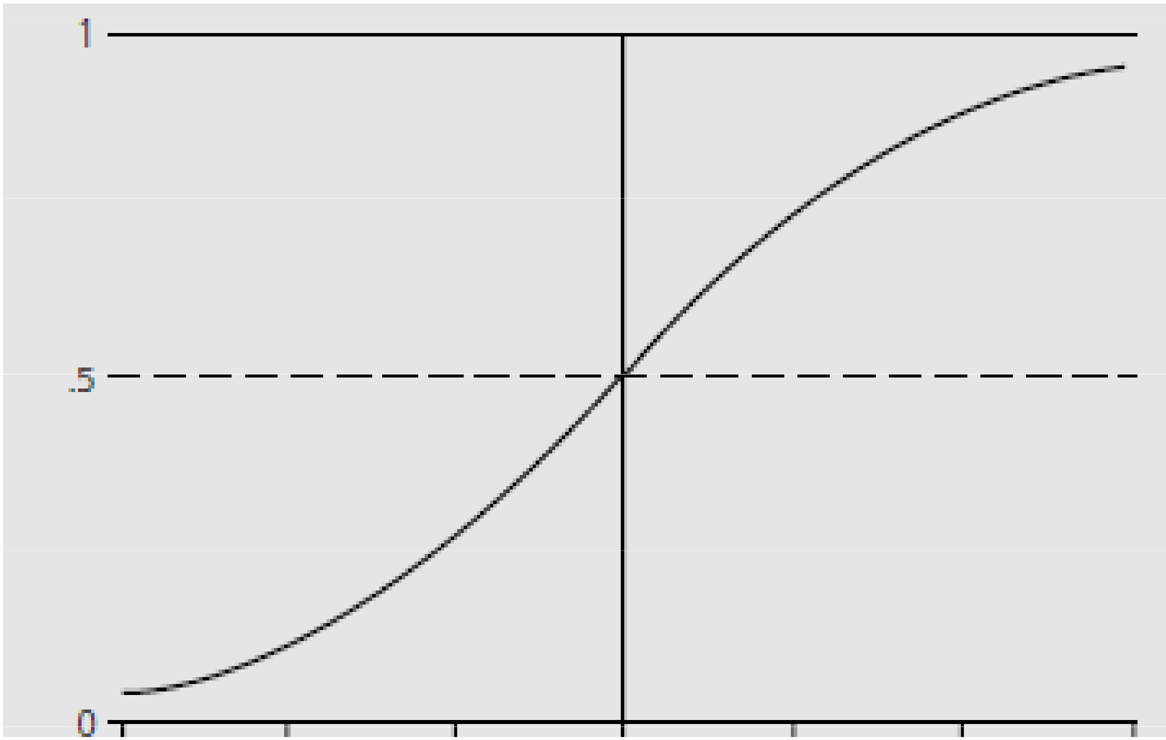
where F is a distribution function.

Logistic distribution function

- What is the form of the distribution function F?
- Although there are many such statistical functions from which to choose, the distribution function which has been found to be must useful in transportation analysis is a logistic distribution function.
- The logistic distribution function for random variable X is:

$$F(x) = \Pr(X \leq x) = \frac{1}{1 + e^{-x}}$$

The cumulative logistic curve



Logit model

Adopting the logistic distribution function for our random utility probability model, replace x with the observed difference in indirect utilities $V_a(p_{Ta}; Y; \phi)$ - $V_b(p_{Tb}; Y; \phi)$. This defines the probability of taking an automobile to be:

$$P_a = F\big(V_a(p_{Ta}, Y; \phi) - V_b(p_{Tb}, Y; \phi)\big) = \frac{1}{1 + e^{-(V_a - V_b)}}$$

$$= \frac{e^{V_a}}{e^{V_a} + e^{V_b}}$$

Binary logit model

- This probabilistic choice model is reffered to as binary logit model of transporattion choice.
- It is a binary model because only two choices are available to the trip maker and it is a logit model because the model is based upon a logistic distribution function.
- Since the probability of taking an automobile plus the probability of taking a bus must add up to one, $P_b = 1 - P_a$, which can be easily shown to be equivalent to

$$P_{\mathrm{b}} = \frac{\mathrm{e}^{V_{\mathrm{b}}}}{\mathrm{e}^{V_{\mathrm{a}}} + \mathrm{e}^{V_{\mathrm{b}}}}$$

Generic and alternative specific variable

In order to estimate our binary logit model, we need to identify the observable parts of consumer's indirect utility function. Assume:

$$V_a = \beta_1 p_{Ta} + \beta_2 Y$$
$$V_b = \beta_1 p_{Tb} + \beta_3 Y$$

Generic variable = when marginal effect of a variable is assumed to have same impact on the indirect utility of each alternative (price)

Alternative specific variable = when marginal effect of a variable depends upon the alternative (income)

Transportation choice model - estimation

$$\square_a = \frac{\exp(\square_1 \square_{\square a} + \square_2 \square)}{\exp(\square_1 \square_{\square a} + \square_2 \square) + \exp(\square_1 \square_{\square b} + \square_3 \square)}$$

$$= \frac{\exp(\square_1 \square_{\square a})\exp(\square_2 \square)}{\exp(\square_1 \square_{\square a})\exp(\square_2 \square) + \exp(\square_1 \square_{\square b})\exp(\square_3 \square)}$$

$$= \frac{1}{\exp(\square_1 \square_{\square a} - \square_1 \square_{\square a})\exp(\square_2 \square - \square_2 \square) + \exp(\square_1 \square_{\square b} - \square_1 \square_{\square a})\exp(\square_3 \square - \square_2 \square)}$$

$$= \frac{1}{1 + \exp(\square_1(\square_{\square b} - \square_{\square a}) + (\square_3 - \square_2)\square)}$$

$$= \frac{1}{1 + \exp\left(-\square_1(\square_{\square a} - \square_{\square b}) - \bar{\square}\square\square\right)}$$

Normalizing alternatives

- Because $\bar{\beta}$ gives the marginal impact of income on automobile choice relative to its impact on bus choice, the bus alternative is said to be a normalizing alternative.

$$V_a = \beta_1 p_{Ta} + \bar{\beta} Y$$
$$V_b = \beta_1 p_{Tb}$$

The choice of normalizing alternative is arbitrary and will have no impact upon the estimated demand for bus and automobile choices. However, the choice of normalizing alternative does affect the interpretation of Y's coefficient.

The demand curve

Holding constant the price of bus travel and income, gives relationship between probability of choosing an automobile and the price of an automobile trip.

$$\Delta P_a / \Delta p_{Ta} = P_a(1-P_a)\beta_1 < 0 \quad \text{for } \beta_1 < 0$$

Elasticities

$$E_{p_{T\mathrm{a}}}^{P_\mathrm{a}} = \frac{\Delta P_\mathrm{a}}{\Delta p_{T\mathrm{a}}}\frac{p_{T\mathrm{a}}}{P_\mathrm{a}} = P_\mathrm{a}(1 - P_\mathrm{a})\beta_1 \frac{p_{T\mathrm{a}}}{P_\mathrm{a}} = (1 - P_\mathrm{a})\beta_1 p_{T\mathrm{a}}$$

$$E_{p_{T\mathrm{b}}}^{P_\mathrm{a}} = \frac{\Delta P_\mathrm{a}}{\Delta p_{T\mathrm{b}}}\frac{p_{T\mathrm{b}}}{P_\mathrm{a}} = -P_\mathrm{a}P_\mathrm{b}\beta_1 \frac{p_{T\mathrm{b}}}{P_\mathrm{a}} = -P_\mathrm{b}\beta_1 p_{T\mathrm{b}}$$

$$E_{Y}^{P_\mathrm{a}} = \frac{\Delta P_\mathrm{a}}{\Delta Y}\frac{Y}{P_\mathrm{a}} = P_\mathrm{a}(1 - P_\mathrm{a})\left(\bar{\beta}\right)\frac{Y}{P_\mathrm{a}} = (1 - P_\mathrm{a})\bar{\beta}Y$$

$$E_{Y}^{P_\mathrm{b}} = \frac{\Delta P_\mathrm{b}}{\Delta Y}\frac{Y}{P_\mathrm{b}} = -P_\mathrm{b}P_\mathrm{a}\left(\bar{\beta}\right)\frac{Y}{P_\mathrm{b}} = -P_\mathrm{a}\bar{\beta}Y$$

Value of time estimates

$$V_{\mathrm{a}} = \beta_1 p_{T\mathrm{a}} + \beta_2 Y + \kappa t_{\mathrm{a}}$$

$$V_{\mathrm{b}} = \beta_1 p_{T\mathrm{b}} + \beta_3 Y + \kappa t_{\mathrm{b}}$$

$$0 = \Delta V = \beta_1 \Delta p_{T\mathrm{a}} + \kappa \Delta t_{\mathrm{a}} \Rightarrow -(\Delta p_{T\mathrm{a}} / \Delta t_{\mathrm{a}}) = \kappa / \beta_1$$

$$0 = \Delta V = \beta_1 \Delta p_{T\mathrm{b}} + \kappa \Delta t_{\mathrm{b}} \Rightarrow -(\Delta p_{T\mathrm{b}} / \Delta t_{\mathrm{b}}) = \kappa / \beta_1$$

$$P_{\mathrm{a}} = \frac{\exp(\beta_1 p_{T\mathrm{a}} + \beta_2 Y + \kappa t_{\mathrm{a}})}{\exp(\beta_1 p_{T\mathrm{a}} + \beta_2 Y + \kappa t_{\mathrm{a}}) + \exp(\beta_1 p_{T\mathrm{b}} + \beta_3 Y + \kappa t_{\mathrm{b}})}$$

$$= \frac{1}{1 + \left(\exp \beta_1 (p_{T\mathrm{b}} - p_{T\mathrm{a}}) + \kappa (t_{\mathrm{b}} - t_{\mathrm{a}}) + \bar{\beta} Y\right)}$$

Multinominal logit - estimation

$$\square_{\square} = \Pr\left(\widehat{\square}_{\square} > \widehat{\square}_{\square}\right)$$

$$= \Pr\left(\square_{\square} + \square_{\square} > \square_{\square} + \square_{\square}\right)$$

$$= \Pr\left(\square_{\square} - \square_{\square} < \square_{\square} + \square_{\square}\right), \quad \square = 1, \ldots\ldots, \square;\ \square \neq \square$$

$$\square_{\square} = \frac{e^{\square_{\square}}}{e^{\square_1} + e^{\square_2} + \cdots .. + e^{\square_{\square}}} = \frac{e^{\square_{\square}}}{\sum_{\square=1}^{\square} e^{\square_{\square}}}, \quad \square = 1, \ldots\ldots, \square$$

$$\square_1 = \square\square_{\square 1} + \square\square_1 + \square_1 \square$$

$$\square_2 = \square\square_{\square 2} + \square\square_2 + \square_2 \square$$

$$\square_3 = \square\square_{\square 3} + \square\square_3 + \square_3 \square$$

$$\vdots$$

$$\square_{\square} = \square\square_{\square\square} + \square\square_{\square} + \square_{\square} \square$$

$$\square_{\square} = \frac{\exp\left(\square\square_{\square\square} + \square\square_{\square} + \square_{\square}\square\right)}{\sum_{\square=1}^{\square} \exp\left(\square\square_{\square\square} + \square\square_{\square} + \square_{\square}\square\right)} = \frac{\exp\left(\square\square_{\square\square} + \square\square_{\square} + \bar{\square}_{\square}\square\right)}{\sum_{\square=1}^{\square} \exp\left(\square\square_{\square\square} + \square\square_{\square} + \bar{\square}_{\square}\square\right)},$$

$$\square = 1, \ldots\ldots, \square$$

Multinominal logit - elasticities

$$E_{P_{ij}}^{x_{ij}} = (1 - P_{ij})\, x_{ij}\beta \qquad \text{"own-" elasticity,} \quad j = 1, \ldots\ldots, J$$

$$E_{P_{ij}}^{x_{ik}} = -P_{ik}\, x_{ik}\beta \qquad \text{"cross-" elasticity,} \quad k = 1, \ldots\ldots, J;\ k \neq j$$

$$E_{j}^{x} = \bar{\beta}_j x - \left(\sum_{k=1}^{J-1} \bar{P}_k \beta_k \right) x$$

for nonnormalized alternatives, $j = 1, \ldots\ldots, J - 1$

$$E_{J}^{x} = -\left(\sum_{k=1}^{J-1} \bar{P}_k \beta_k \right) x$$

for normalized alternative *J*, $k = 1, \ldots\ldots, J - 1$

3.2 Urban transportation mode choice

Binary logit model

Background

- In order to fix ideas developed in the previous sections, lets examine a typical study of work-trip mode choice in which two alternative modes are available, automobile and public transit.

Work trip modal split and average travel time, 1990

Region of Country	Automobile Work Trip	Public Transit Work Trip	Average Travel Time to Work
New England	94.7	5.3	21.5
Middle Atlantic	83.9	16.1	25.7
East North Central	95.6	4.4	20.7
West North Central	98.0	2.0	18.4
South Atlantic	96.5	3.5	22.5
East South Central	98.8	1.2	21.1
West South Central	98.0	2.0	21.6
Mountain	97.8	2.2	19.7
Pacific	95.0	5.0	23.8

Source: Department of Commerce, *1993 Statistical Abstract of the United States*

Domenich – McFadden (1975)

- Binary logit model for automobile and public transit base upon a sample od 115 commuter trips.
- The analysis focused upon a suburban and downtown corridor in the Pittsburgh metropolitan area.
- Of the 115 trip-makers, 54% commuted by automobile and 46% by public transport.
- For each of the commuters, the observable indirect utilities for automobile and public transport respectively were:

Observable indirect utilities

$$V_a = \beta_0 + \kappa_1(\text{Time}_a) + \beta_1(\text{Cost}_a) + \beta_2(\text{Autos/Worker}) + \beta_3(\text{Race}) + \beta_4(\text{White Collar})$$

$$V_b = \kappa_1(\text{Time}_{pt}) + \kappa_2(\text{Walk Time}) + \beta_1(\text{Cost}_{pt})$$

Specification

(1) Time and cost are generic variables, since the marginal effect of travel time and travel costs on indirect utility is assumed to be the same for the automobile and public transit modes, respectively.

(2) Observed indirect utility for the automobile includes three alternative specific variables: Automobile/Worker, Race and White Collar. They are called alternative specific variable, because each is associated with a specific alternative, automobile choice.

(3) β_0 is difference between the indirect utility of automobile choice and bus choice.

Hypotheses

1) By the law of demand we expect:

$\kappa_1 < 0$, $\beta_1 < 0$, $\kappa_2 < 0$

2) Income plays role in consumption + household use of automobile is constrained by the numbers of automobile available. Therefore: $\beta_2 > 0$

3) Socioeconomic characteristics such as Race and White Collar are included to reflect differences in preferences among consumers in automobile travel. A priori, however, we have no basis for expecting these variables to have a positive or negative sign.

Estimation results (1)

	β_0	k_1	β_1	β_2	β_3	β_4	k_2
Automobile utility price	1	Time_a	Cost_a	Autos per Worker	1 if nonwhite	1 if white-collar job	0
Public Transit Utility	0	Time_{pt}	Cost_{pt}	0	0	0	Walk time
Coefficient Estimate (*t*-statistic)	−3.82 (−7.48)	−0.0382 (−1.51)	−0.0256 (−4.45)	4.94 (4.62)	−2.91 (−2.12)	−2.36 (−2.02)	−0.158 (−3.30)

Source: Domenich and McFadden (1975), p. 159

Estimation results (2)

Modes: auto, public transit

Variable	Coefficient Estimate	*t*-statistic
Constant (auto)	–3.82	–7.48
Time (all modes)	–0.0382	–1.51
Cost (all modes)	–0.0256	–4.45
Autos/Worker (auto)	4.94	4.62
Race (auto)	–2.91	–2.12
White-collar (auto)	–2.36	–2.02
Walk Time (public transit)	–0.158	–3.30

Source: Domenich and McFadden (1975), p. 159

Demand

1) All else constant, an increase in the cost of automobile trip to work reduces Pa, the probability of taking an automobile to work.

2) The coefficient estimate of Time is negative, which implies that higher automobile and bus travel times, respectively, decrease the probability of taking an automobile or bus in the journey to work.

3) An increase in Walk Time means that the bus stop is further away and, all else constant, is expected to reduce the probability of taking a bus in the work trip.

Change in the demand

Policy Change*	Percentage Point Change in P_a	P_b
1 cent increase in auto cost	–0.64	+0.64
1 cent increase in bus cost	+0.64	–0.64
1 minute increase in auto time	–0.95	+0.95
1 minute increase in bus time	+0.95	–0.95
1 minute increase in walk time	+3.9	–3.9

* Each policy is based on the assupmtion that P_a = 54% and P_b = 46%.

Automobile choice elasticities

Elasticity with Respect to	Automobile Choice	Bus Choice
Automobile Cost*	–0.59	+0.69
Bus Cost	+0.59	–0.69
Automobile Time**	–0.53	–0.62
Bus Time ***	+0.53	+0.62
Walk Time ****	+1.09	–1.28

* Elasticity evaluated for a current travel cost equal to $0.50, P_a = 0.54, and P_b = 0.46.
** Elasticity evaluated for a current travel time equal to 30 minutes, P_a = 0.54, and P_b = 0.46.
*** Elasticity evaluated for a current walk access time equal to 15 minutes, P_a = 0.54, and P_b = 0.46.

Modal demands and the value of time

- The coefficient Walk Time is more than four times as large as coefficient estimate for Time.
- Value of Travel Time –0.0382/-0.0256 = 1.49 cents/minute =0.89 USD/hour.
- Value of Walk Time –0.158/-0.0256 = 6.17 cents/minute =3.70 USD/hour.
- Important implications for he design of transport facilities.

3.3. Intercity demand for travel

Background

- The private automobile is still the primary mode of travel, accounting for four fifths of all passenger miles in 1990 (USA).
- What explains the continued dominance of the automobile for intercity trips? Given the relatively high price of airline tickets, why don't more travelers take bus or rail in their intercity trips? And do all intercity travelers value their time the same, or can we identify a relationship between value of time and mode taken?
- In order to answer these questions, we shall analyze an intercity travel demand model for leisure (non-business) related trips.

Specification of indirect utility

- Data: 1977 survey in the USA. 3623 vacation travelers. 69,3% vacationers traveled by automobile; 24,8% by air and 2-3% by bus and rail respectively.
- Morrison and Winston (1985) estimated a multinomial logit intercity demand model for single destination trips.
- A leisure travelers indirect utility for intercity travel is assumed to depend upon five basic determinants:
  - A mode's round-trip cost
  - The round-trip travel time
  - The average time between scheduled departures
  - The number of people travelling together
  - Household income

Hypotheses

(1) It is expected that each of the travel cost and travel time variables will have a negative sign.

(2) According to labor-leisure choice theories of labor supply, an individual's opportunity cost of time is related to one's wage rate. This implies that the marginal effect on indirect utility from an increase in travel time will be greater for higher income households than for lower income households.

(3) Because the marginal cost of an extra traveler in an automobile trip is very low, it is expected that it will increase demand for automobile travel.

(4) The presence of small children will increase demand for automobile on shorter and decrease it on longer trips.

Estimation results (1)

Variables	Coefficient Estimate	*t*-statistic
Cost-related characteristics		
Round-trip cost, in dollars (auto)	−0.0064	−1.22
Round-trip cost, in dollars (bus)	−0.0031	−1.27
Round-trip cost, in dollars (rail)	−0.0031	−1.57
Round-trip cost, in dollars (air)	−0.0028	−1.97

Estimation results (2)

Time-related characteristics		
Round-trip time, in minutes (auto)	−0.00013	−0.85
Round-trip time, in minutes, for household with income < $20,000 (bus)	−0.00038	−2.60
Round-trip time, in minutes, for household with income ≥ $20,000 (bus)	−0.0016	−1.57
Round-trip time, in minutes, for household with income < $20,000 (rail)	−0.00037	−1.58
Round-trip time, in minutes, for household with income ≥ $20,000 (bus)	−0.00099	−2.69
Round-trip time, in minutes (air)	−0.0014	−1.16
Average time between scheduled departures, in minutes, for household with income < $20,000 (bus)	−0.0019	−2.27
Average time between scheduled departures, in minutes, for household with income ≥ $20,000 (bus)	−0.0039	−1.01
Average time between scheduled departures, in minutes (rail)	−0.00058	−0.39
Average time between scheduled departures, in minutes (air)		

Estimation results (3)

Socioeconomic chararacteristics		
Number of travellers (auto)	0.622	4.61
Number of travellers less than 4 years of age and trip distance less than 400 miles (auto)	1.33	1.29
Number of travellers less than 4 years of age and trip distance greater than 400 miles (auto)	−0.67	−2.82
Mode preferences constant terms		
Constant term (bus)	−1.18	−3.68
Constant term (rail)	−0.75	−2.52
Constant term (air)	−0.38	−0.81

Source: Morrison and Winston (1985), table 1, p. 220. The model also included a rental car variable which was found to have no effect upon intercity modal demands

The demand curves for intercity travel

- Consistent with expectations and with law of demand, the coefficient estimates for each of the travel time and travel cost variables are negative, giving us an inverse relationship between opportunity cost and choice probability.
- Marginal disutility of cost is nearly identical for the common carrier modes (bus, rail and air), whereas cost plays a smaller, and somewhat less significant, role in the demand for automobile travel.

Elasticity

	Elasticity with Respect to		
Mode	Cost	Travel Time	Time Between Departures
Auto	–0.955	–0.393	–
Bus	–0.694	–2.11	–1.23
Rail	–1.20	–1.58	–1.27
Air	–0.378	–0.434	–0.047

Source: Morrison and Winston (1985), table 3, p. 226

Value of time estimates

Mode		Value of Travel Time (% of wage)	Value of Time Between Departures (% of wage)
Auto	All households	0.63 (6)	–
Bus	Households with incomes < $20,000	4.33 (79)	21.67 (394)
	Households with incomes ≥ $20,000	14.03 (87)	33.87 (210)
Rail	Households with incomes < $20,000	4.37 (79)	5.98 (58)
	Households with incomes ≥ $20,000	8.80 (54)	5.98 (58)
Air	All housholds	15.37 (149)	2.32 (23)

Source: Morrison and Winston (1985), table 2, p. 224

Policy implications

- The USA is seriously considering the viability of high speed rail system. Given an estimated capital cost 16-30 mil. USD per mile, these system must have a large ridership to be economically viable.
- Based on the results HSR will be viable in dense population centers and for trips that are medium travel range 200 – 400 miles.

3.4. Household demand for vehicle ownership

Vehicle ownership by number of adults in households

	Number of Vehicles (%)			
Number of Adults	0	1	2	3 or More
One-adult households				
1969	56.2	42.3	1.5	–
1977	39.2	53.2	5.7	1.9
1983	34.0	57.1	7.1	1.8
Two-adult households				
1969	12.4	57.3	29.1	1.2
1977	7.5	33.1	48.2	11.2
1983	5.8	29.2	49.7	15.3
Three-adult households				
1969	8.2	32.2	42.6	17.0
1977	5.9	15.9	34.4	43.8
1983	5.6	13.5	27.1	53.8
All households				
1969	20.6	48.4	26.4	4.6
1977	15.3	34.7	34.4	15.6
1983	13.5	33.7	33.5	19.3

Source: US Department of Transportation, Federal Highway Administration, *1983–84 Nationwide Transportation Study*

Vehicle ownership by household income, 1983

Number of Vehicles	< $10,000 (%)	$10,000–$19,999 (%)	$20,000–$29,999 (%)	$30,000–$39,999 (%)	> $40,000 (%)
0	39.5	8.8	2.3	1.5	1.1
1	42.8	46.2	30.4	17.7	12.2
2	13.6	31.6	44.8	49.7	43.8
3	3.1	10.2	15.2	20.5	25.5
≥4	1.0	3.2	7.3	10.6	17.4

Source: Department of Transportation, Federal Highway Administration, *1983–1984 Nationwide Transportation Study*

Indirect utility for vehicle ownership

$$V_0 = 0$$

$$V_1 = \alpha_0 + \alpha_1 \log(\text{Household Income}) + \alpha_2(\#\text{Workers})$$
$$+\alpha_3 \log(\text{Household Size}) + \alpha_4(\text{Transit Trips per Capita})$$
$$+\gamma(\text{Average Utility from Vehicle Type Choice})$$

$$V_2 = \beta_0 + \beta_1 \log(\text{Household Income}) + \beta_2(\#\text{Workers})$$
$$+\beta_3 \log(\text{Household Size}) + \beta_4(\text{Transit Trips per Capita})$$
$$+\gamma(\text{Average Utility from Vehicle Type Choice})$$

Hypotheses

1) Increase in household income increases the demand for automobile ownership → $\alpha_1 > 0$ $\beta_1 > 0$.
2) The greater the supply of public transport, the lower is the opportunity cost of using public transportation → $\alpha_4 < 0$ $\beta_4 < 0$.
3) Increases in demand for automobile travel are expected to increase the level of ownership → $\alpha_2 > 0$ $\alpha_3 > 0$ $\beta_2 > 0$ $\beta_3 > 0$.
4) The more closely current household fleet matches its needs, the greater is the probability of owning that number of vehicles → $\gamma > 0$.

Household demand for vehicle ownership

Explanatory Variable	Coefficient Estimate	*t*-statistic
Logarithm of Household Income (1)	1.05	3.69
Logarithm of Household Income (2)	1.57	3.52
Number of Workers in Household (1)	1.08	3.78
Number of Workers in Household (2)	1.50	4.78
Logarithm of Number of Household Members (1)	0.181	0.43
Logarithm of Number of Household Members (2)	0.197	0.39
Annual Number of Transit Trips per capita in household's area of residence (1)	–0.0009	–1.82
Annual Number of Transit Trips per capita in household's area of residence (2)	–0.0021	3.42
Average Utility from Vehicle Type Choice (1, 2)	0.635	7.14
Constant term (1)	–1.79	–2.97
Constant term (2)	–4.95	–5.19

Note: Ownership levels: 0 = no vehicles; 1 = one vehicle; 2 = two vehicles.
Source: Train (1986), table 8.1, p. 146

Effects on vehicle demands from income increases

Demand for	Income Elasticity	Effect of 1% Increase in Income on the Percentage Point Vehicle Demands
No vehicles	–1.18	–0.159
One vehicle	–0.133	–0.045
Two vehicles	0.387	0.204

Note: Evaluation based upon initial demands given by $P_0 = 0.135$, $P_1 = 0.337$, and $P_2 = 0.528$.

Effects on increase in per capita transit trips on vehicle demands

Demand for	Per Capita Transit Trips Elasticity (%)	Effect of 1% Increase in Income on the Percentage Point Vehicle Demands*
No vehicles	5.0	0.67
One vehicle	1.81	0.61
Two vehicles	–2.44	–1.28

Note: Evaluation based upon an 35.4 average annual household number of public trips per capita in the area and initial vehicle demands given by P_0 = 0.135, P_1 = 0.337, and P_2 = 0.528.
* Calculated using equation (4.32), where $\bar{\beta}_1 = -0.0009$, $\bar{\beta}_2 = -0.0021$, and z is the annual number of transit trips in the respondent's residential area.

3.5. Summary

Summary (1)

- Discrete transportation demands, such as choice of travel mode to work, are of an "either–or" nature and it is not possible to consume both simultaneously. Analysis of discrete choice commodities entails comparing the indirect utility of one alternative with the indirect utility of other available alternatives. A consumer's indirect utility function gives the highest possible level of economic welfare for a given economic environment. A consumer's indirect utility function is positively related to a rise in income and negatively relative to a rise in prices.

Summary (2)

- Among a set of discrete transportation choices, a consumer maximizes economic welfare by choosing the transportation alternative with the highest level of conditional indirect utility. For these alternatives, changes in the economic environment occur at the extensive margin as consumers switch from one alternative to another.

Summary (3)

- Because only part of a consumer's indirect utility function is observable, a consumer's choice of a discrete transportation alternative occurs with some probability. The probabilistic model that characterizes welfare-maximizing choices among a set of discrete transportation alternatives is referred to as the random utility model. Random utility models of transportation choice characterize the demands for each of the alternatives available to the decision-maker. In random utility models, observation errors primarily reflect taste differences among the population rather than measurement or optimization errors.

Summary (4)

- When two transportation choices are available, a very common empirical model is the binary logit random utility model. When more than two alternatives are available, the binary logit model easily generalizes to a multinomial logit model. In addition to characterizing existing demands, logit models of transportation choice are used to forecast the market share of new alternatives. In discrete choice models, generic variables are those whose marginal impact upon indirect utility is common across the available alternatives; an alternative specific variable is one whose marginal impact upon indirect utility is specific to a particular transportation alternative.

Summary (5)

- Because travel time and travel cost typically characterize transportation choices, empirical random utility models provide a convenient method for estimating the value that consumers place upon their travel time. The value corresponds to the estimated coefficient of the travel time variable divided by the estimated coefficient of the travel cost variable.
- In random utility models of transportation choice, all available alternatives are substitutes in consumption. An increase in the opportunity cost of a given alternative reduces the probability of selecting the alternative, but shifts the probability demand curves of the other alternatives to the right.

Summary (6)

- Consistent with other studies, an analysis of transportation mode choice in the trip to work indicates that workers are sensitive to a mode's travel time and travel trip to work indicates that workers are sensitive to a mode's travel time and travel cost. In addition, workers' mode choices are more sensitive to out-of-vehicle time than in-vehicle time. Workers' choices were twice as sensitive to an increase in walk time relative to travel time. Also consistent with other studies, workers in this analysis valued out-of vehicle time much more highly than in-vehicle travel time.

Summary (7)

- In a case study of intercity modal choice for nonbusiness-related trips, modal choices were sensitive to a mode's transportation cost. In addition, an increase in travel time on a public conveyance had a much greater disutility effect on rail and bus relative to air travel; and, holding all else constant, travelers prefer to travel by air or auto relative to making a trip by bus or rail. Among the modes, the choice of rail mode was most elastic to a change in cost and the choice of bus mode was most elastic to a change in travel time. As a percentage of their wage rate, air travelers place the greatest value on their travel time, but bus travellers place the highest value on the time between departures (in part due to the disutility of time spent at bus stations).

Summary (8)

- Over the past 30 years, there has been a significant increase in automobile ownership, due to a general increase in the standard of living. After controlling for household size, the availability of public transit, and the number of workers, a case study of automobile ownership in the USA confirms that household ownership is strongly influenced by household income. An increase in household income is expected to decrease nonownership and single vehicle ownership to the benefit of multiple vehicle ownership. But, importantly for public transit policy, vehicle ownership is sensitive to the availability of public transit. The demands for nonownership, single vehicle ownership, and multi-vehicle ownership were elastic with respect to the availability of public transit.

Summary (9)

- Consistent with expectations, a case study of carrier choice by freight shippers found that an increase in the transport rate charged or a decrease in a carrier's service reliability reduced the probability of a shipper selecting the carrier. But shippers were more sensitive to reliability than to the rate charged. In addition, shippers were found to be sensitive to the inventory transit cost. Further, among three carrier modes studied – truck, rail, and piggyback – shippers preferred truck carriers, all else constant, which reflects the greater flexibility of truck carriage to the two other modes.