2. TRANSPORTATION DEMAND

The Divisible Goods Case

2.1.Theory

The theory of consumer demand

- Assumptions (complete, transitive and nonsatiable preferences)
- Indifference curves
- Budget constraint
- Consumer equilibrium

Demand function

- Indifference curves and demand function
- Individual demand function
- Market demand function

Change in quantity demanded versus change in demand

Increase in Demand from $D_T(p_T)$ to $D_T''(p_T)$ Due to:	Decrease in Demand from $D_T(p_T)$ to $D_T'(p_T)$ Due to:
Increase in income	Decrease in income
Increase in population	Decrease in population
Decrease in price of complements	Increase in price of complements
Increase in price of substitutes	Decrease in price of substitutes
Decrease in taxes on T	Increase in taxes on T
Increase in preferences for T	Decrease in preferences for T

Demand for transportation - estimation

- Identical customers
- Non-identical customers

2.2. The demand for gasoline

Background

- 94% of all motor vehicle trips in USA were taken in private transportation
- 80,7 % of total intercity travel was done in passenger cars
- 45,7 % of all petroleum consumption is by personal cars

Research question

- Given the dominance of motor vehicle travel in the USA, are consumers sensitive to changes in its price?
- In the 1993 national budget discussions, there was a considerable interest in raising the gasoline tax, both for its effect on deficit reduction and for its potential in reducing urban congestion and pollution.
- Holding all else constant, an increase in the federal gasoline tax is expected to reduce the quantity of gasoline consumed. But by how much? Is the demand for gasoline price elastic or price inelastic?

Research question

- A related question concerns governmental policy that alters the manner in which gasoline is allocated.
- By the mid-1970s, price controls on oil were still in effect.
- Because price controls prevent the monetary price of gasoline from rising, what impact did the price controls have on the opportunity cost of gasoline when the 1973-4 oil crisis hit?

The demand for gasoline in California

To answer these questions, the demand for gasoline must be estimated. In a study on monthly gasoline demands and automobile travel in California, Lee (1980) assumed the market demand for gasoline in California, G_t, to be:

$$
\begin{aligned}
G_t^0 = {} & \beta_0 + \beta_1(\text{Real Gas Price})_t + \beta_2(\text{Real Income})_t + \\
& + \beta_3(\text{Population})_t + \sum_{t=1}^{11} \psi_i S_{ti} + \tau_1 \text{DEC73} + \\
& + \tau_2 \text{JAN74} + \tau_3 \text{FEB74} + \tau_4 \text{MAR74} + \tau_5 \text{APR74} + \varepsilon_t
\end{aligned}
$$

Hypotheses

(1) By the law of demand β_1 is expected to be negative

(2) Each of the gasoline crisis variables reduces the consumption of gasoline, all else hold constant

(3) Estimated effect of gasoline crisis on the opportunity costs of gasoline is positive

(4) Gasoline is a normal good $\rightarrow \beta_2 > 0$

(5) $\beta_3 > 0$

Estimation results

Dependent variable – average daily consumption of gasoline per month (‘000s)

Explanatory Variable	Coefficient Estimate	*t*-statistic
Constant	–25,193.1	–3.38
Real Gasoline Price ($)	–18,552.8	–5.34
Real Income (billion $)	277.3	6.29
Population (millions)	1,567.9	2.92
DEC73	–1,801.5	–2.84
JAN74	–1,629.7	–2.57
FEB74	–2,313.1	–3.60
MAR74	–2,524.1	–3.88
APR74	162.7	0.25
$R^2 = 0.92$		

Source: Lee (1980), table 2, p. 40. Lee did not report the coefficient estimates for the seasonal dummy variables

Demand curve

Hypothesis 1

- Estimated coefficient for β_1 is negative and significant → downward slope of demand curve.
- 95 % confidence interval for β_1 is (-25,8; -11,3)

Hypothesis 2

Because of the increased time cost, brought on by the gasoline crisis, average daily consumption fell by 1,8 million gallons.

Change in the demand

Hypothesis 3

Given that average daily consumption was approximately 25 million gallons, the results indicate that in march 1974, the gasoline crisis resulted in a 10% reduction in gasoline consumption.

Hypothesis 4

A 1 billion dollar increase in real personal income leads to a 277000 gallon increase in average daily gasoline consumption.

Hypothesis 5

Additional person increases daily demand by a bit more than one and half gallons per day.

Elasticities

The price elasticity of demand is defined as:

$$\frac{\Delta G / G}{\Delta RPG / RPG} = \frac{\Delta G}{\Delta RPG}\frac{RPG}{G} = \beta_1 \frac{RPG}{G}$$

- Replacing β_1 with 18,552 and RPG and G with their respective sample means, Lee calculated the gasoline price elasticity of demand to be –0.216 → the demand for gasoline is inelastic.
- The data are monthly, covering five year period, the rice elasticity is short run. Long run price elasticity of demand are considerably higher and have been estimated to be around -0.8.
- Employing a similar procedure, the income elasticity of the demand for gasoline was calculated to be 0.876 → gasoline is a normal good.

Queuing cost premia

- What was the queuing cost associated with the gasoline crisis?
- From estimation results, an estimate of queuing prices for each month of the crises can be obtained by dividing the month's coefficient by β_1.
- Table reports these estimates which are positive and consistent with hypothesis 3.
- The queuing cost represent a significant portion of the total opportunity cost.

	December 1973	January 1974	February 1974	March 1974	April 1974*
Monetary	31.3	32.4	32.6	35.7	36.7
Time price	9.7	8.8	12.5	13.4	–
Opportunity cost	41.0	41.2	45.1	49.1	36.7

* A time price for April 1974 was not calculated because the price shock coefficient for this month was not significantly different from zero.

Source: Lee (1980), table 4, p. 41

The demand for trips

Dependent variable – average daily trips during each month ('000s)

Explanatory Variable	Coefficient Estimate	t-statistic
Constant	−1,211.080	−7.51
Real Gasoline Price ($)	−370.235	−4.93
Real Income (billion $)	4,578.8	4.80
Population (millions)	65,660.1	5.66
DEC73	−20,744.1	−1.51
JAN74	−20,841.2	−1.52
FEB74	−51,063.3	−3.68
MAR74	−87,070.6	−6.19
APR74	−6,221.3	−0.44
$R^2 = 0.97$		

Source: Lee (1980), table 2, p. 40. Lee did not report the coefficient estimates for the seasonal dummy variables

The demand for gasoline x trips

- The impact of price, income and population was same and significant.
- However gasoline crisis variables were stronger in demand for gasoline than for trips. Why?
- We would expect demand for trips to be less responsive to gasoline price increases than for gasoline because, in the shirt run, there re more substitution opportunities for reducing fuel than for reducing the number of trips.

The 1993 gasoline tax increase

- According to the 1993 Deficit Reduction Bill, passed in late 1993, the federal gasoline tax increased by 4.3 cents per gallon. With average per gallon price equal to USD 1.06, this represents an approximate 4% increase in the 1993 real price of gasoline.
- The above results found price elasticity of demand for gasoline to be – 0.216 and for trips -0.236.
- The federal gasoline tax increase can be expected to have reduced the quantity of gasoline demanded by 0.86% and average daily trips by 0.94%.
- At the national level, this translates into a 1.74 million gallon daily reduction in the demand for gasoline and 5.68 fewer automobile trips per day.

Comments

- A potential deficiency of the model is the lack of information on relevant alternatives. Economic theory tells us that demand depends on price of substitutes.
- Is this important? Possibly, but not necessarily.

2.3. The demand for urban rail rapid transit

Background

- Heavy rail public transport systems = high-speed electric railways that carry high traffic volumes on multi-car trains and have separate rights of way
- Their advantage over conventional bus systems is the more competitive line haul speeds and grater comfort. At the same time, by their very nature, heavy rail systems are fixed in place and, accordingly, less able to accommodate changing business and residential land-use patterns.
- In addition, they are very capital intensive

Heavy rail transit systems, USA 1991

Largest City Associated with Fixed Rail System	Heavy Rail Trips (millions)	Percentage of All Public Transit Trips in City
New York	1,358.8	61.3
Washington DC	188.3	51.2
Boston	172.2	54.3
Chicago	147.6	22.9
Philadelphia*	85.3	24.8
San Francisco	76.1	31.8
Atlanta	67.1	46.9
Miami	13.9	18.7
Baltimore	12.8	12.0
Philadelphia**	11.4	n/a
Cleveland	6.4	9.6
Total	2,166.9	25.1

*Operated by the Southeastern Pennsylvania Transportation Authority.

**Operated by the Port Authority Transit Corporation (PATCO) of Pennsylvania and New Jersey.

Source: American Public Transit Association 1992: *1992 Transit Fact Book.* Washington DC (Table 34,pp. 69–70)

Trends in heavy rail transit ridership, 1980 - 1990

Year	Heavy Rail Passenger-Miles (millions)	Public Transit Total Passenger-Miles (millions)	Heavy Rail as a Percentage of Total Miles
1980	10.558	39.854	26.5
1982	10.049	37.124	27.1
1984	10.111	39.424	25.6
1986	10.649	40.204	26.5
1988	11.300	40.580	27.8
1990	11.475	41.143	27.9

Source: American Public Transit Association 1992: *1992 Transit Fact Book.* Washington DC (Table 38, p. 78)

Research question

- The people moving capabilities of heavy rail systems emphasize the role that these systems play in alleviating congestion in our nations major urban centers and reducing motor vehicle emissions and air pollution
- But before we can develop urban transit policies to induce travelers on to heavy rail systems, we must identify what factors determine a travelers decision to use a heavy rail system

Case study

- Doi and Allen (1986) analyzed the demand for rapid rail transit trips in Philadelphia for a particular rapid rail link (HS, 14.2 mile) between southern New Jersey and downtown Philadelphia.
- At the time of the study, transit services were provided 24 hours a day, 7 days a week, with an average daily ridership of 38.000 – 40.000.
- For this particular link, bus services are not a relevant alternative, but automobile travel is.

Demand

The demand for this high-speed line was expressed as a linear function of its own price, prices associated with the primary alternative mode, and seasonal variables. In particular,

$$
\begin{aligned}
RR_t^0 = {} & \square_0 + \square_1(\text{Real Transit Fare}) + \square_2(\text{Real Gas Price})_t + \\
& + \square_3(\text{Real Bridge Toll})_t + \square_1(\text{Summer Months}) + \\
& + \square_2(\text{October}) + \square_3(\text{Closure}) + \square_t
\end{aligned}
$$

- RR_t^0 is observed rapid rail transit ridership in month t.
- Real transit fare (dollars) is the price of an average trip on the line.
- Real Gasoline Price (dollars per gallon) and Real Bridge Toll (dollars per crossing) correspond to the price by the most relative alternative – automobile.
- Summer months is a dummy variable (May – September) to capture a seasonal downturn due to school and family vacations.
- October captures various sports and cultural events combined with absence of national holidays producing an increase in ridership in this month.
- Closure captured the effect of one closed station for reconstruction.

Hypotheses

(1) $\beta_1 < 0$ (the law of demand)

(2) $\beta_2 > 0$ $\beta_3 > 0$ (assumed substitution between rail and automobile)

(3) $T_3 < 0$ (opportunity costs)

Estimation results

Dependent variable – monthly rapid rail ridership

Explanatory Variable	Coefficient Estimate	*t*-statistic
Constant	818,900	–
Real Transit Fare	–383,499	–5.63
Real Gas Price	234,048	4.36
Real Bridge Toll	928,064	4.16
Summer Months	–52,815	–10.88
October	40,273	4.59
Closure	–20,783	–2.04
$R^2 = 0.78$		

Source: Reprinted from Doi and Allen (1986), with permission from Elsevier Science. The *t*-statistic for the constant term was not reported

Demand

- Consistent with law of demand, an increase in the price of rapid rail transit trips decrease the quantity of rapid rail trips demanded.
- A dollar increase in the per gallon price of gasoline produces a rightward shift in the demand curve for rail transit, increasing monthly trips by 234.048.
- A dollar increase in the bridge toll increase transit trips but the effect is nearly quadruple.

Closure and opportunity costs

- Closing a stations was expected to decrease the demand by raising the opportunity cost.
- Coefficient – 20.783 represents the monthly loss in rapid transit patronage.
- It is possible to estimate the impact of station closure on opportunity cost:

$$\frac{\Delta ???_{?}}{\Delta \text{Closure}} = \frac{\Delta ???_{?}}{\Delta \text{Opportunity Cost}} \frac{\Delta \text{Opportunity Cost}}{\Delta \text{Closure}}$$

$$?_3 = ?_1 \frac{\Delta \text{Opportunity Cost}}{\Delta \text{Closure}}$$

- From estimation results can be calculated the estimated increase in rail rapid cost (-20.783/-383.499) = 0.054 dollars.
- That is, closure of the rail rapid stations imposed an additional 5.4 cents on the opportunity cost of rapid rail travel.

Own and cross-price elasticities

The own price elasticity of the demand:

$$\frac{\Delta RR/RR}{\Delta \text{Fare}/\text{Fare}} = \beta_1 \frac{\text{Fare}}{RR}$$

,where Fare and RR are replaced by their sample averages. The own price elasticity was estimated as -0.233 → demand is price inelastic.

The cross price elasticity for demand for rapid rail with respect to the price of gasoline is defined as:

$$\frac{\Delta RR/RR}{\Delta \text{Real Gas Price}/\text{Real Gas Price}} = \beta_2 \frac{\text{Real Gas Price}}{RR}$$

Using sample averages, the cross price elasticity was found to be 0.113. Similarly, the cross price elasticity of demand with respect to bridge tolls was found to be 0.167.

The 1993 gasoline tax increase revisited

- We return to the predicted effects of the 4.3 cent rise in the federal gasoline tax.
- Assume that 0.113 is representative of all rapid rail trips.
- Since increase of tax represent an approximate 4% increase in the price of gasoline this implies (4)(0.114) = 0.452% increase in ridership.

2.4. The demand for short – haul air services

Intercity domestic travel

	Private Carrier		Public Carrier		
Year	Automobile*	Air**	Air	Rail***	Bus****
1965	817.7 (89.2)	4.4 (0.5)	53.7 (5.9)	17.6 (1.9)	23.8 (2.6)
1970	1,026.0 (86.9)	9.1 (0.8)	109.5 (9.3)	10.9 (0.9)	25.3 (2.1)
1975	1,170.5 (86.4)	11.4 (0.8)	136.9 (10.1)	10.1 (0.7)	25.4 (1.9)
1980	1,120.3 (82.5)	14.7 (1.0)	204.4 (13.9)	11.0 (0.7)	27.4 (1.9)
1985	1,130.3 (80.1)	12.3 (0.8)	277.8 (17.0)	11.3 (0.7)	23.8 (1.4)
1990	1,597.5 (80.2)	13.0 (0.6)	345.9 (17.4)	13.2 (0.7)	23.0 (1.1)

* Includes small trucks for travel purposes.
** General aviation, including air taxi and small air commuter.
*** Includes long-haul intercity and short-haul commutation but not urban rail transit.
**** Excludes urban bus transit.
Source: ENO Transportation Foundation 1993: *Transportation in America*, 11th edn

Background

- Airline Deregulation Act of 1978
- Result of deregulation – hub and spoke orientation of airlines
- Hub and spoke system = lower costs, lower revenues (opportunity costs)
- Niche market = short haul commuter market linking nonhub smaller communities to the nearest largest hub city

Research question

- Although many such niches may exist, the airline must determine whether there is sufficient demand for profitable services
- Pickrell (1984) investigated this problem and specified the market demand function for short haul commuter trips between a smaller nonhub community and the nearest airline hub city as:

Demand

$$\begin{aligned}\ln(\text{Trips})_t^0 = {} & \beta_0 + \beta_1 \ln(\text{Fare})_t + \beta_2 \ln(\text{Flytime})_t + \\ & + \beta_3 \ln(\text{Freq})_t + \beta_4 \ln(\text{Seats}) + \\ & + \beta_5 \ln(\text{Enplanements}) + \beta_6 \ln(\text{Drvcost}) + \\ & +\beta_7 \ln(\text{Drvtime}) + \beta_8 \ln(\text{Population}) \\ & +\beta_9 \text{Cert} + \varepsilon_{ti}\end{aligned}$$

Trips is the number of one way trips from the smaller nonhub city to the larger hub city. Fare is the published air fare for a trip. Flytime is the scheduled flying time. Freq is the number of weekly departures form the origin to the destination. Seats is the average seating capacity per departure. Enplanements is the total number of passneger enplanements at the hub city. Drvcost is the estimated out of pocket expenses if the trip were made by automobile. Drvtime is the estimated travel time of the trip by the automobile. Population is the poulation in the community from which the trip originate and Cert is a dumy variable that equals one if the route is serviced by a Civil Aeronautic Board (CAB) certificated airline and zero otherwise.

Logarithmic form

- In contrast to the examples for automobile travel and rapid rail transit, all variables except for the constant term and Cert are specified in logarithmic form
- This in no way alters the interpretation of specification as a market demand function for shirt haul commuter trips
- However, it does assume that he determinants of short haul air travel interact multiplicatively in forming demands and that elasticities of demand are constant.
- This latter point becomes clear once we recall that the parameters estimates in double log model are elasticities

Hypotheses

(1) Since increases in airline fares and time related costs raise the opportunity costs of air travel, by the law of demand it is expected that $\beta_1 < 0$ $\beta_2 < 0$ $\beta_3 < 0$. Larger aircraft is usually more comfortable, therefore: $\beta_4 > 0$.

(2) A higher number of enplanements at the destination city reflects a greater level of economic activity as well as improved opportunities for connecting flights. Therefore: $\beta_5 > 0$. CAB certificate reflects underlying preferences of consumers and it is expected: $\beta_9 > 0$

Hypotheses

(3) Cities with larger populations are expected to have more consumers of short – haul air travel, increases in population are expected to shift the demand for short haul trips rightward, all else constant. Thus, it is expected: $\beta_8 > 0$.

(4) Drvcost and Drvtime are included to reflect the opportunity cost of an automobile trip: $\beta_6 > 0$ $\beta_7 > 0$

Estimation results

Dependent variable – logarithm of the number of one-way air passenger trips

Explanatory Variable	Coefficient Estimate	*t*-statistic*
Constant	−0.487	–
ln(Fare)	−1.08	−2.45
ln(Flytime)	−1.85	−4.24
ln(Freq)	0.58	4.10
ln(Seats)	0.32	1.14
ln(Enplanements)	0.36	2.80
ln(Drvcost)	−0.0003	−0.30
ln(Drvtime)	1.86	3.44
ln(Population)	0.109	0.66
Cert	0.61	1.76
$R^2 = 0.42$		

* The *t*-statistics for the constant term was not reported. The parameter estimates reported here were obtained from a simultaneously estimated model of supply and demand. The supply function specified departures to be a function of the number of passenger trips and plane capacity.

Source: Pickrell, D. 1991: The regulation and deregulation of US airlines. In Button, K. (ed.), *Airline Deregulation: International Experiences*. David Fulton (Table 2.2, p. 26)

Size x frequency

- An interesting implication of the results relates to decisions regarding the frequency of service and size of aircraft.
- Should an air carrier provide fewer departures per week and use larger aircraft or increase weekly departure frequency but use smaller aircraft?
- Seats → positive, but insignificant.
- Frequency → positive and significant. The increased frequency should increase ridership.

Demand determinants

- Drvcost does not include airport parking costs.
- In absolute terms, the coefficient for driving time is almost identical to the coefficient of flying time → travel time is an important determinant and in this case equally sensitive.
- Population is insignificant, therefore employment could be a better variable.
- Price elasticity is close to unity.

2.5. Summary

Summary (1)

- A consumer's utility function describes the level of economic welfare that the consumer receives from alternative bundles of commodities. The utility function also depends upon the consumer's preferences, which are assumed to be complete, transitive, and nonsatiable.

Summary (2)

- An indifference curve is a locus of points that reflects alternative commodity bundles which provide a consumer with equal amount of economic welfare. Typically, a consumer's set of indifference curves are convex to the origin, indicating that the more a consumer has of one good the fewer other goods he or she is willing to give up to obtain an additional unit of the good. This reflects the principal of diminishing marginal rate of commodity substitution.

Summary (3)

- If a consumer optimally allocates his or her limited resources among competing goods, then for each pair of commodities consumed, the marginal rate of commodity substitution equals the commodity's relative price. In equilibrium, a consumer's demand for each commodity depends upon relative prices, income, and preferences. Changes in the economic environment cause individuals to alter their consumption of goods at the intensive margin.

Summary (4)

- The market demand for transportation is the horizontal summation of individual demands for transportation. A change in the price of transportation leads to a change in the quantity of transportation demanded. A change in any other determinant of transportation leads to a change in demand.
- Goods that are consumed together are complements in consumption. A rise in the price of one good decreases the market demand for the other good. Goods that compete with one another in consumption are substitutes. A rise in the price of a substitute good increases the market demand for the other good. A good whose consumption increases (decreases) with increases in income is a normal (inferior) good.

Summary (5)

- For continuous or divisible transportation commodities, observed transportation demands are approximated by a linear-in-parameters empirical model. Ideally, the explanatory variables of the model include the price of the transportation good, the prices of related goods, and income. Socioeconomic characteristics are included in the empirical model in order to capture preference differences among demanders. Differences between observed transportation demands and predicted demands reflect consumer optimization or measurement errors.

Summary (6)

- Because transportation trips involve the movement of people or goods over space, the opportunity cost of transportation includes both a monetary cost and a time cost. Increases in each component of cost is expected to reduce the quantity of transportation demanded. Case studies for energy and automobile trip demands in California, urban transit trips in Philadelphia, and short-haul commuter airline trips are consistent with these expectations.
- Empirical models of transportation demands not only identify relevant determinants of demand but also provide estimates on the magnitude of the effects that changes in the economic environment will have upon demands. This information facilitates improved public and private decision-making in the transportation sector.