Lecture 5 - Transportation

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1 Transportation

1. Up to now transportation has played two roles in analysis
   (a) Transportation cost paid to commute or ship goods to the center, $t \cdot x$
   (b) One reason for the existence of a city. All businesses send exports to center because there are IRS to scale in shipping for export, i.e. docks, rail hub, airport
2. This treatment is unsatisfactory in many ways
   (a) Supply of transport services
      i. What determines transport cost t?
      ii. More generally, what economic factors affect production, investment, ownership and pricing?
      iii. What is the theory of transportation infrastructure investment?
      iv. How are transport services produced and by whom?
      v. Public vs. private provision? Why is so much transportation capital owned by the public sector? Why are transport services often provided by the public sector?
      vi. How are these issues related to the pricing of transport services? Are transportation services efficiently priced?
   (b) Externalities associated with transport sector

i. Congestion
ii. Pollution (air, water, noise)
iii. Accidents and safety externalities

(c) Demand for transport

i. In the simple spatial equilibrium model, people decided to commute or not. In reality, they also choose how to commute. They choose a mode of transportation. How do we extend our analysis to study multiple modes of transport? Multiple destinations?
ii. They also choose when to travel.
iii. Demand for transport varies depending on time of day, destination, and mode of travel. Utility or productivity depends on each of these factors. During peak hours many people have a high demand for transport. During off-peak hours, fewer do. The benefits to travel are higher for high value destinations such as the city centre but lower for other destinations. Some people prefer to travel by car, some by train, and others by bus.
iv. A model of transport demand should be flexible enough to capture these aspects of reality.

3. Implications of these issues for economic policy. Each of the above points has implications for public policy toward transport infrastructure, the shape of cities, and the spatial organization of cities

(a) Nature of supply affects relative costs of different modes.

(b) Nature of demand affects relative benefits.

(c) Externalities associated with different modes have multiple policy implications.

(d) Several reasons why private utility and profit maximisation potentially does not result in social welfare maximisation in the transport sector. Leading to potential rolls for policy

i. Natural monopoly
ii. Contracting costs
iii. Externalities: congestion, pollution and accidents

iv. Creates potential role for taxation/subsidization, regulation, public provision

2 Economic analysis of transportation

1. Goals of economic analysis of transportation

   (a) Theoretical model of supply, demand, government policy, and externalities:

      i. Understand efficiency and equity considerations of alternative arrangements

      ii. Potential complications due to distortions in economy that might arise due to government intervention, monopoly behaviour, externalities

      iii. When private incentives are different from social incentives, possibility for distortion, inefficiency

      iv. Seek normative understanding of what government should try to do

         A. Tax

         B. Regulation

         C. Infrastructure investment

         D. Public vs private provision

   (b) Measure costs and benefits of different modes of transport

      i. Costs of supply

      ii. Externality, monopoly, and costs of government distortion

      iii. Benefits to users, consumers

   (c) Problem: how to measure?

      i. Costs of supply: relatively easy, see how much is spent providing different modes

      ii. Externality costs: measure of damage caused by pollution, injury, congestion

      iii. Benefits: how to measure, observe choices households make and how households trade off money against benefits of transportation. How much is household willing to pay to speed up commute by one mile an hour

(d) Predict how demand and supply will respond to technological developments, demographic changes, policy choices

i. Incentives facing consumers, suppliers, and government for each mode

ii. How to measure?

3 Key economic characteristics of the supply of transport services

1. Transport is capital intensive.

   (a) One of the most important inputs for any transport mode or sector is the fixed cost associated with the underlying infrastructure. For automobile transport, a fixed cost must be incurred to build roads. For trains, rails must be constructed. For boats, a river or a canal must be maintained. For air travel, airports and traffic control need to be invested in. As a result of these heavy fixed costs, these industries are increasing returns to scale industries. Because of this, the provision of transport infrastructure is a natural monopoly. In the absence of government intervention, the monopoly provider of the infrastructure is likely to provide too little at too high a price in order to maximise profits. Two common methods that attempt to address this problem are: a) public provision of infrastructure, b) government regulation of privately provided transport infrastructure.

   (b) A second important input in transport is the vehicle/carriage/train/rolling stock/boat/etc. This input is also an important fixed cost in providing transport. This capital input is sometime provided by firms, sometimes by governments, and sometimes by consumers.

   (c) An important technological constraint that governs the relative efficiency of organizational arrangements concerning infrastructure and vehicles, is the cost of contracting or coordinating the services provided by the two forms of capital. For trains, the costs of coordinating the services of the rail infrastructure and independent rolling stock is often relatively high. For automobiles, the costs of

coordinating the services of the road infrastructure and the vehicles is relatively low. That is one reason why rail providers and train providers tend to be integrated while road providers and car providers tend not to be integrated.

2. A model.

   (a) Let demand for transportation be

$$y = d(p).$$

   (b) Let production cost under private provision be

$$\begin{aligned} C(y) &= kn + cy \\ y &= \sum_{i=1}^{n} y_i \end{aligned}$$

   where k is the fixed cost, n is the number of firms, c is the marginal cost, and y_i is the supply of firm i.

   (c) Costs are minimised when there is one firm.

   (d) Monopoly solution is

$$\max_{\{p\}} \{d(p)\, p - k - cd(p)\}$$

   with first order conditions

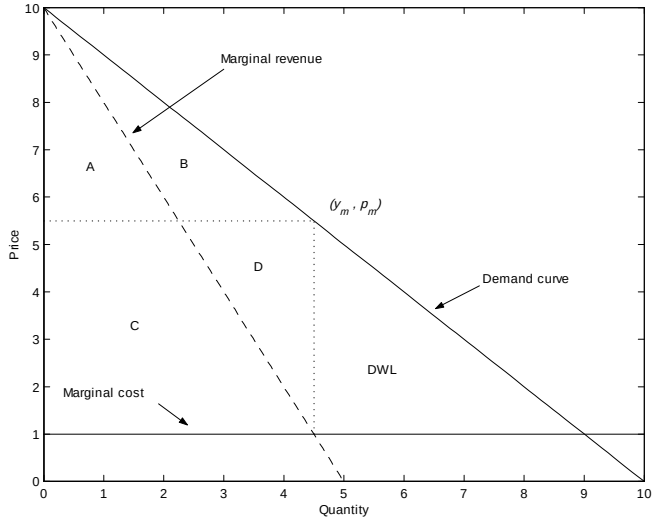
$$\begin{aligned} d(p) + (p-c)\frac{\partial d}{\partial p} &= 0 \qquad (1) \\ \frac{d(p)}{p \cdot \left(-\frac{\partial d}{\partial p}\right)} &= \frac{p-c}{p} \\ \frac{1}{\varepsilon} &= \frac{p-c}{p} \end{aligned}$$

   where

$$\varepsilon = \frac{p}{d(p)}\frac{\partial d}{\partial p}$$

   is the elasticity of demand and $\frac{p-c}{p}$ is the percentage markup of price over marginal cost. This formulation shows that the optimal markup of the monopolist depends on the elasticity of demand.

Figure 1: Monopoly pricing



(e) Or alternatively,

$$\max_{\{y\}} \left\{ y d^{-1}(y) - k - cy \right\}$$

with first order conditions

$$\begin{aligned} d^{-1}(y) + y\frac{\partial d^{-1}(y)}{\partial y} - c &= 0 \\ d^{-1}(y) + y\frac{\partial d^{-1}(y)}{\partial y} &= c \end{aligned}$$

where $d^{-1}(y)$ is the inverse demand curve. This formulation is equivalent to (1). It shows that the optimal quantity of the monopolist is the one that equates marginal revenue to marginal cost.

(f) The solution is shown in Figure 1.

- (y_m, p_m) is the monopoly quantity and price determined by the intersection of the marginal revenue curve and the marginal cost curve
- DWL is the deadweight loss relative to efficient pricing
- The area A+B is the consumer surplus at the monopoly solution

i. Calculate consumer surplus for the linear demand curve.

- The area C+D is the profit of the monopolist before paying the fixed cost

(g) It is possible for a monopolist to price and achieve an efficient solution. Suppose that the monopolist could charge a fixed fee such as an annual fee for road use and then charge a per unit fee of p_e. Then the monopolist could set

$$p_e = c \tag{2}$$

and $f_e = A+B+C+D+DWL$. This would be efficient. However, consumers would retain no surplus. All the surplus would go into monopoly profits. This solution requires the monopolist to be able to make a "take it or leave it" offer.

(h) Regulated outcome: Government requires price satisfies (2) and restricts $f = \frac{k}{d(p_e)} < f_e$ so that the monopolist earns zero profits. This solution is efficient and allows the monopolist to recover the costs of providing the service.

i. Problem: The monopolist has incentive to lie to the regulator about the values of k and c. The monopolist has incentive to report $k_r > k$ and/or possibly $c_r > c$.

ii. If it is costly for the government to monitor or audit the monopolist's costs, then the actual regulated outcome will be

$$\begin{aligned} f_r &= \frac{k + k_r}{d(p_r)} \\ p_r &= c + c_r \end{aligned}$$

where $(k_r, c_r) \neq (k, c)$ due to imperfect monitoring and due to monitoring costs. To the extent, $k_r > k$ or $c_r > 0$, there will be increased monopoly profits and there will be some deadweight loss. Additionally, any component of these costs that primarily is spent on monitoring or on dealing with the regulatory body is effectively wasted resources. Any component of (k_r, c_r) that is not spent on monitoring or on regulating, is effectively a transfer from consumers to the monopolist.

iii. The regulated outcome will NOT be socially desirably if costs of regulation and/or monitoring are high; especially if much

of the rent is spent seeking to deceive regulators as to the true values of (k, c).

(i) Public ownership outcome. Government runs the system and sets efficient price.

i. When regulatory costs are high, it may be more efficient to have the public sector run the transport industry. This will be efficient if the costs of government management are lower than the costs of maintaining and enforcing the regulatory system.

ii. A new potential problem arises here in that the government costs or providing the service may be higher than private costs. The monopoly has an incentive to minimise cost. Cost minimisation is concomitant with profit maximisation. The government transport ministry may not have the proper incentives to minimise costs. First, since its managers do not work for a profit maximising firm, it may be costly to give them the proper incentives to minimise costs. Second, the government may have other objectives in addition to maximising the economic value of the transport industry. The government may also want to use public ownership of the industry to transfer resources from rich to poor, or from poor to rich, or from rich and poor to middle class, or from urban households to rural households or from households to public sector workers. This will in general increase the costs of providing transportation. Is this an efficient mechanism to transfer resources? Is this a desirable transfer of resources? If so, then such a policy might be a good idea and public ownership will improve social welfare. If not, then public ownership will in general reduce welfare. In this case, an alternative mechanism to redistribute resources should be used (such as the tax and benefit system). In this case, it is better to privatise the transport system, and either move closer to efficiency through regulation or allow the monopolist to set efficient two part prices.

iii. The public ownership outcome is $k_g > k$ and/or $c_g > c$ so

outcome is

$$\begin{aligned} f_f &= \frac{k_g}{d\left(p_g\right)} \\ p_g &= c_g > p_e \end{aligned}$$

(j) In summary,

i. Private monopoly (when two part tariffs are not feasible) is inefficient and results in transfer from consumers to monopoly.

ii. Private monopoly (with two part tariff) results in efficient outcome but with zero consumer surplus. Maximal value of monopoly profits. This has good efficiency properties but perhaps bad distributional properties. If this distribution of rents is NOT desirable, a solution might be a tax on monopoly profits that is used to redistribute wealth to households. Such a tax may be politically difficult to implement and also entails its own monitoring and enforcement costs.

iii. Regulated monopoly is efficient and can achieve any desired distribution of rents as long as monitoring and regulatory costs are zero. If these costs are small enough, this system will be optimal. However, if these costs are large, this system will not be desirable.

iv. Public ownership. This system is efficient if public management costs are small and if incentives of public sector managers can be aligned with cost minimisation. This system may also be desirable if it is a good mechanism to redistribute rents in the economy.

(k) Vertical integration

i. Monopolist provides rail infrastructure at cost

$$C_0 = k_0 + c_0\left(y_1 + y_2\right).$$

ii. Two rail companies provide rail services at cost

$$\begin{aligned} C_1 &= k_1 + f_1 + b_1 + c_1 y_1 \\ C_2 &= k_2 + f_2 + b_2 + c_2 y_2 \end{aligned}$$

A. (k_0, k_1, k_2) are fixed capital costs of providing infrastructure and rolling stock respectively

B. (f_1, f_2) are the fixed fees that rail operators must pay to monopolist

C. (b_1, b_2) are bargaining and contracting costs

D. (c_1, c_2) are marginal costs of providing rail services (including per unit payments from rail operator to monopolist)

iii. This system could be beneficial if competition between 1 and 2 leads to competitive pricing of rail services.

A. Bertrand competition in prices results in both 1 and 2 charging competitive prices.

B. Cournot competition in quantities results in both 1 and 2 charging prices that are higher than competitive prices but lower than monopoly prices.

iv. However, bargaining and contracting costs can be very high. If these costs are high, then this system will not be efficient.

4 Externalities.

1. Main externalities associated with transportation

   (a) Congestion

   (b) Pollution

   (c) Accidents and safety externalities.

2. Government policies

   (a) Taxes and subsidies

   (b) Tradeable permits

   (c) Regulations on number of cars, emissions, pollution controls, safety standards, highway construction standards, speed and traffic control

5 Congestion and pricing

1. Congestion is a problem, externality.

(a) Externality.

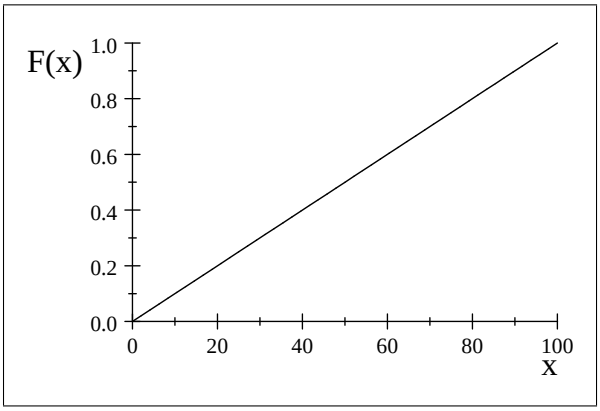
(b) Policies: Taxes, quotas, regulations.

(c) Long run issues, investment.

(d) Realistic pricing: tolls, gas tax, parking tax, subsidize public transit

2. Congestion model.

(a) In a simple economy, there are N consumers. All the consumers commute to work either by train or by car on the public highway. If they commute by car the personal or private cost of travel is $C(n_d)$ where n_d is the total number of drivers on the highway. For example, it might be the case that $C(n_d) = F + n_d$. The cost of travel on the highway rises with the number of drivers on the highway. The cost of highway travel is the same for every consumer on the highway. For each person on the train, however, the cost of travel is c_i. Each person i has a different cost of train travel perhaps because each person lives at a different distance from the train station. We assume that $c_i \in [0, 100]$ and that c_i has a distribution in the population that is uniform between 0 and 100. That is, $c_i \in [0, 100]$ and if one picks an arbitrary number x between 0 and 100, then the fraction of the population with c_i less than x is $\frac{x}{100}$. This can also be viewed graphically. Let $F(x)$ equal the fraction of the population with c_i less than x. Then $F(x) = \frac{x}{100}$



Fraction of population with c_i less than x

The graph shows for instance that, $\frac{1}{10}$ the population has cost c_i less than 10. $\frac{1}{2}$ the population has cost less than 50. $\frac{6}{10}$ has cost less than 60. The total number of people in the city is N. The total number with cost less than x is $\frac{Nx}{100}$.

(b) Each consumer uses the mode of transport that is cheapest.

(c) Demand for highway travel

i. Suppose the cost of highway travel is c_h. All the people who have c_i larger than or equal to c_h prefer to drive. All who have $c_i < c_h$ prefer

ii. Let n_h be the number of people who prefer driving to using the train.

iii. How many people have $c_i \geq c_h$?

$$n_h = N\left(1 - \frac{c_h}{100}\right)$$

iv. This is the demand for highway travel.

3. Equilibrium in congestion model.

(a) Demand for road travel satisfies

$$n_h = N\left(1 - \frac{c_h}{100}\right)$$

(b) But, by assumption

$$c_h = C\left(n_d\right)$$

where n_d is the number of drivers.

(c) An equilibrium results when $n_h = n_d$. That is when the number of people who want to drive on the highway equals the number of people on the highway.

(d) Compute equilibrium in a special case. Suppose $C\left(n_h\right) = F + n_h$. Then

$$n_h = N\left(1 - \frac{F + n_h}{100}\right)$$

$$n_h\left(\frac{100 + N}{100}\right) = N\left(1 - \frac{F}{100}\right)$$

$$n_h = \frac{N\left(100 - F\right)}{100 + N}$$

(e) If $N = 100$

$$n_h = \frac{100 - F}{2}.$$

(f) Draw the picture with n_h on the horizontal axis and c_h on the vertical axis.