BASIC TRANSPORTATION ECONOMICS

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192

Introduction

Under the terms of this workshop, the lectures are to be published basically in the original form which you heard in the class. In the matter of revision, I have made only small adjustments in order to preserve the flavor of the original lecture. I mention this partly because lectures, like sermons, do not make books. No matter how resonant and uplifting they sound, at least to the lecturer during presentation, they remain unimpressive in print. With this caveat in mind, the reader is introduced to the session titled "Basic Transportation Economics."

The Scope of Transportation

Transportation economics is the application of economic principles to the examination of issues in various modes of transportation. It is usually not treated as a separate discipline but rather as a mix of general transportation and applied microeconomic theory.

The occasion of this lecture seems an appropriate moment to evaluate the general state of transportation as a profession, science, art, or however one may view it. In making this evaluation, it would be helpful to observe the significant areas of transportation and to indicate to you where economics fits in. As a starting point, one might classify transportation into five general areas: (1) transportation engineering, (2) transportation planning, (3) transportation policy, (4) transportation regulation and law, and (5) transportation economics.

The first of these areas is transportation engineering, in which there are the two sub-areas: "hardware" and "software." Hardware pertains to analysis in the actual production of transportation equipment and invokes the use of traditional engineering principles. The software area, which involves the application of analytic tools and techniques to transportation problems, would include systems analysis, demand modelling, and computer programming applications.

The second area of transportation is transportation planning, which develops a decision-making apparatus to handle the social, political, and environmental aspects of a multitude of current and future problems at urban, regional, and national levels. The third area refers to transportation policy, the "piece de sustenance" of all transportation analysts. Issues of transportation policy can range widely from the question of labor featherbedding to SST investment to subsidy for mass transit systems. To this area I have added logistics and physical distribution management, that is, the management of the movement of physical goods from points of origin to points of destination.

The fourth area of transportation regulation and law will comprise a substantial portion of this seminar and its activities concerning the air sector will be explained accordingly. This brings us to the fifth area of transportation economics, the use of economic analysis in transportation.

<u>Transportation Economics</u>

Economics evolved in the eighteenth and nineteenth centuries as an attempt to explain and to justify a market system. The coordinating and controlling mechanisms in those centuries were the competitive markets and the systems of prices that emerged from the bargains between freely contracting buyers and sellers. The rationalization of the competitive market is still in large measure relevant to most advanced economies today. For all the great modifications to which market economies have been subjected in practice during the twentieth century and for all the qualifications that must be attached the case for such an economy, the competitive market model is still an important measure (in some ways--essential) descriptive both of reality and of the aggregate conception of what an ideal economic system should be.

Yet there are at least two large sectors of the U.S. economy that the competitive market model cannot even purport to describe. These are the huge and growing public sector,where the allocation of resources is determined mainly by political decisions, and the regulated sector in which the organization and management are mostly private but the central economic decisions are subject to direct governmental regulation. In general, industries which fall under the aegis of the various independent regulatory commissions may be classified into communications, banking and finance, energy, public utilities, and transportation. In these instances the primary guarantor of acceptable activity is conceived to be not competition or self-restraint but direct governmental prescription of major aspects of their structure and economic performance. Transportation industries are distinguished from other sectors of the economy by four principal components of this regulation: control of entry, fare and rate fixing, the prescription of quality and conditions of service, and the imposition of an obligation to serve all users under reasonable conditions. Transportation economics then is an analysis of the economics of that regulation--its characteristics and consequences, the principles that govern it, and the principles by which it ought to be governed.

If you read today the classic treatise of two centuries ago by Adam Smith on the Wealth of Nations[1], you would note that he submitted three general propositions which have provided the basis of economic analysis over the decades. These three propositions in paraphrase form are the following:

> First, that the wealth of a nation is the product of its labor;
> Second, that the greatest improvements in the product of labor result from the division of labor; and
> Third, that the division of labor is limited by the extent of market.

Now to these three propositions I would add a fourth which many economists, especially regional economists, have argued: the extent of the market is controlled by the cost of transportation. If you interpret these four propositions in a syllogistic fashion, you could argue the linkage between transportation cost and the wealth of a nation. If the nation's wealth can be measured by the national income accounts, GNP statistics reflect quite clearly the importance of the transportation sector.

In terms of economic analysis one must distinguish between the different modes of transportation because the institutional arrangement,

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[1]Adam Smith, An Inquiry Into the Nature and Causes of the Wealth of Nations, Edwin Cannan edition, London: Methuen and Co., Ltd., 1925.

managerial practices, and market structure are very different in the air, rail, water, motor and pipeline industries. The analysis must indicate the distinctions between passenger and freight traffic, between intercity and urban movements, and between domestic and international transportation. Even in the case of a single mode, the analyst must define the scope of his study very carefully. As an example, the analysis for evaluating TACV would be very different from examining AMTRAK or previous intercity rail passenger service with conventional technology because neither the immediate nor long-run effects of TACV are known.

Especially since each economic analysis requires stringent assumptions about the constancy of all variables except the ones under focus, it is essential for the analyst to specify each time the location, environment, and time period to which his analysis is applicable. In technical terms, this feature is referred to as "ceteris paribus"--everything else being equal--and the analysis is known as one of partial equilibrium.

In terms of the above scope of an analysis of transportation economics, one also must keep in mind that there are several components to the total transportation picture involving the actual users of transportation, the firms (carriers) which are providing the services, the extent of government agency participation, and the impacts on nonusers (or what is often referred to as the public interest elements). An economic analysis conducted solely at the user level in urban transportation might suggest different policy implications than an analysis at the firm or agency level since firms and users often have different interests and are striving for different objectives. Many riders in the Boston corridor may be interested in free transit but the MBTA cannot offer commuter services at zero fares unless large subsidies were involved. The cross-effects on nonusers as a result of the income transfers necessary to pay for these subsidies and the increasing role of governmental involvement would complicate the analysis.

Market Structure, Conduct, and Performance

How are these components best treated simultaneously? In terms of most effectively solving the total picture by using the airline industry as an example[2]: first, we look at how the firms or agencies are structured in offering the air transportation service to the public, namely, how are they organized, how large are they, how do they compete? Why do we have trunk line carriers? Why are there supplementals? Why do we have local air carriers? Why cargo carriers? In terms of an economic analysis of the air transport industry, market structure refers to the degree of competition, the size distribution of firms, absolute size, types of competition, and barriers to entry. In general, market structure pertains to the ways in which airline firms are organized and the resulting structure of firms from such organizations. Just as the credibility of a demand or cost analysis depends on the specification of a location and time period, so does the merit of a market structure analysis require the specification of relevant markets (routes) and types of service.

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[2]The total picture of transportation can be portrayed in Figure 1.

INGREDIENTS AND SCOPE OF TRANSPORTATION ECONOMICS	ANALYSIS BY MODE
Passengers:	(1) Air
- International	(2) Rail
- Domestic	(3) Motor
- Intercity	(a) Auto
- Urban	(b) Bus
	(c) Truck
Commodities (Freight):	(4) Water
- International	(a) Inland
- Domestic	(b) Ocean
	(5) Pipeline
	(6) New Technology

Figure 1

The Total Picture of Transportation Economics

Along the line of the structural elements, a second feature to examine relates to what is called in legal terms market conduct or simply conduct. Market conduct pertains to the ways in which firms or agencies in air transportation behave in relation to the statutory or other legal requirements within the context of their market structure. Issues of certification, route structure, and fares fall into this category.

Related specifically to the conduct area are the ways in which firms and agencies behave with respect to economic yardsticks. This third area refers to what is called economic or market performance. Measures of economic performance would include rates of return on investment, profit rates, number of innovations, returns on research and development, and rates of return on stockholder equity.

From all of this emerges a really basic question: What is the relationship between market structure and market performance? The degree of such a relationship has been an often debated and well documented topic, with proponents ranging from one extreme to the other. Suffice it to say that, if the testimony of many participants in airline merger cases is an indicator, it appears that at least in the airline industry changes in market structure induce changes in market performance. If the C.A.B. in the future regards its adjudicating role in merger cases seriously, then substantial research must be undertaken linking the forecasts of expected changes in economic performance to changes in market structure resulting from merger activities.

Production Functions, Costs, and Demand

How does one go about measuring these variables? Say we want to examine profit to the firm as a measure of performance. From an empirical point of view, we need to have estimates of revenues and costs. In order to forecast revenues, we must estimate a demand function; and to estimate costs, we need some estimate of the underlying production function.

What then is a production function? A production function is merely a behavioral relationship between the inputs required to provide transportation services and the output which is derived (see Figure 2). A very difficult question in terms of transportation, particularly airline transportation, is what is output? This is especially difficult when you encounter the empirical problems of trying to measure output (whether it be seat-miles, departing seats, revenue-seat-miles, number of movements, etc.). For purposes of illustration, let us assume that the input side can be classified by three items: capital, labor, and fuel. The production function then associates this combination of inputs with producing a certain level of output. Again both the location and time period must be carefully specified.

There are numerous types of production functions that can be tested empirically but the most frequently applied type is the multiplicative production function, which could be represented from Figure 3 in the following way: output (Z) is derived from a joint combination of capital (K), labor (L), and fuel (F). The result is a lograithmic production function. Taking natural logs on both sides of the equation yields a log linear equation where the exponents become coefficients and represent the elasticities of output with respect to each of these inputs.

PRODUCTION FUNCTIONS:

TWO VERSIONS

(1) $Z = F(X_1, X_2, \ldots X_n)$

inputs

(2) $Z = F(C, L, V, T, E, D)$

characteristics

Where Z represents output

$X_1, X_2, \ldots, X_n$ represent capital, labor, fuel, etc. and the characteristics can be depicted by cost, level of service, volume, technology, environment, etc.

Figure 2

Two Methods of Specifying Production Functions

$$Z = F(K, L, F)$$

$$Z = AK^{\alpha} L^{\beta} F^{\gamma}$$

$$\alpha + \beta + \gamma \gtreqless 1$$

$$TC = rK + wL + mF + FC$$

<u>OBJECTIVE:</u>

$$\text{minimize } \phi = rK + wL + mF + FC + \Gamma(Z - AK^{\alpha}L^{\beta}F^{\gamma})$$

Figure 3

A Multiplicative Production Function
with Three Inputs

203

For example, in Figure 3, α represents the elasticity of output with respect to capital, β the elasticity of output with respect to labor, and γ the elasticity of output with respect to fuel. The sum of these exponents is a measure of the returns to scale. If the sum equals one, constant returns to scale result, that is, a 10% increase in capital, labor and fuel simultaneously would yield a 10% increase in output or volume (Z). If the sum exceeds one, increasing returns to scale results; if the exponents sum to less than one, then decreasing returns to scale occur (for the same 10% increase in inputs, a less than 10% increase in output would occur).

The use of production functions is becoming the most frequently used procedure for identifying the growth component attributable to progress in all industries, including air transportation. In view of the productivities of the physical inputs in some base period, we can estimate the increase in input that would have occurred since the base period if, given the level of technological knowledge of that period, the increase of output had been brought about merely by the growth of the quantity of physical inputs. The difference between the output growth actually observed and the so calculated hypothetical growth (i.e., the residual) may be regarded as an excellent measure of productivity change. Quite obviously, this measure requires estimates of both inputs and outputs and of the behavioral linkage between the two in the form of the coefficients of the production function.

There are at least three principal reasons for suggesting a production function approach to the development of improved productivity measures in air transportation. One is the general desirability for accuracy, precision, and clarity to facilitate scientific analysis. A second and related reason concerns a particular objective: if we know a priori why we want to measure performance in air transportation, we can then decide what kinds of measures of inputs and outputs are appropriate. Statistical testing then becomes the means by which this appropriateness is determined.

A third reason for being concerned with the production function approach relates to the infrastructure of general cost analysis and to the estimation of cost functions. The statistical estimate of cost functions has been in the strict sense an empirically evasive effort despite the literature being replete with different sorts of estimation attempts. The chief reason for a paucity of meaningful estimates is that rarely are the cost functions related to the behavioral properties of the production functions. In the past researchers in their haste to relate cost to output forgot that in theory and in practice one cannot say anything about the properties of cost functions unless something is known about the underlying properties of the productions from which cost functions can only be derived.

On the assumption that the prices of these inputs are known, that is, the price of capital, the price of labor, and the price of fuel (r, w, and m in Figure 3), one can specify a general cost function which can be derived from the production function. Notice that the cost function (TC) contains a term for fixed cost (FC) in addition to the variable prices above. Another way of expressing a total cost function is to relate costs directly to output (see Figure 4, Equation1). From this traditional cost function (a cubic expression) can be derived a complete set of relationships involving average and marginal costs. These relationships are useful in an airline's determination of short run cost minimization. From Figure 5, notice that the marginal cost curve intersects both the average total cost curve and the average variable cost curve at their minimum points. From the total cost curve, the average cost curve which Professor Tideman drew is total cost divided by Z and the result is a U-shaped curve. The partial derivative of total cost (TC) with respect to Z yields marginal cost. It says neither anything about demand, nor anything about revenues, which must be treated as separate behavioral analyses in order to test for profit maximization conditions.

On the demand side, single equation estimates usually specify a relationship between the quantity demanded of air service and variables such as population, income, and fares. Some analysts would prefer to combine the population and income variables into a single variable called income per capita. A shift in population will cause a direct change in the quantity demanded of air service. A change in the fares will affect the change in quantity demanded but in a negative fashion. When fares increase, by the law of demand, generally the volume will go down, assuming again ceteris paribus.

Several sessions in this workshop will be devoted to issues of demand. In these sessions we will observe a variety of techniques used for forecasting demand including trend analysis, market research approaches, and econometric methods.

The specification of demand is crucial since at any particular time, average fare multiplied by the number of passengers using the services will yield revenues. Keeping in mind that the airline company is pursuing some one or more managerial objectives, like profit maximization, an accurate assessment of revenues is required to offset cost in order to generate profits. Profits are maximized when total revenues exceed total costs by the largest amount for some Z or, as Professor Tideman has demonstrated, when marginal costs equal marginal revenues. These two conditions will occur simultaneously.

In many situations airline companies will be pursuing objectives other than profit maximization yet the foundations for any alternative hypothesis still require an accurate assessment of costs and revenues. In fact, the need for extremely accurate estimates becomes much more compelling as one considers additional alternative objectives. A separate analysis of some of these objectives is the topic of a later session in this workshop. The importance of cost and demand functions will become apparent to you in the topics of other sessions which will focus on issues of competition, regulation, fare levels, excess capacity, growth, and long run survival.

Summary

Transportation economics is an integral part of all transportation activities. We have observed the scope of transportation and the niche which transportation economics occupies in that scope. To the extent

(1) TC (total cost) $= a_0 + a_1 Z - a_2 Z^2 + a_3 Z^3 = TFC + TVC$

(2) TFC (total fixed cost) $= a_0$

(3) TVC (total variable cost) $= a_1 Z - a_2 Z^2 + a_3 Z^3$

(4) ATC (average total cost) $= \frac{TC}{Z} = \frac{a_z}{Z} + a_1 - a_2 Z + a_3 Z^2$

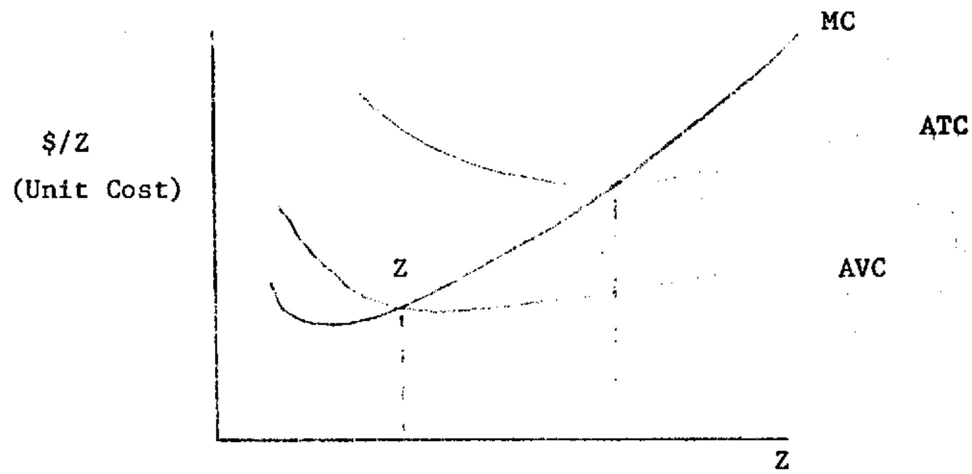
(5) AFC (average fixed cost) $= \frac{TFC}{Z}$

(6) AVC (average variable cost) $= \frac{TVC}{Z} = ATC - AFC$

(7) MC (marginal cost) $= \frac{\partial (TC)}{\partial Z} = a_1 - 2 a_2 Z + 3a_3 Z^2$

Figure 4

Cost Functions



SHORT RUN OPTIMIZATION: MC = ATC

$$MC = \frac{d(TC)}{dZ} = \frac{d(TVC)}{dZ}$$

$$\frac{d(ATC)}{dZ} = 0 \rightarrow MC = ATC$$

Figure 5

Cost Minimization

that there exists a need for more refined, detailed, and careful analyses, we have examined the contributions of the market structure--conduct-performance methodology and the specification of production, cost and demand functions.

210