PROBLEMS WITH SIMPLE VALUATION METHODS

The valuation methods discussed earlier in this chapter have several potential limitations, many of which were discussed earlier. This section focuses on the *omitted variable* problem and *self-selection* bias.

The Omitted Variable Problem

All of the methods discussed thus far in this chapter implicitly assume that all other explanatory variables are held constant, but this is unlikely in practice. Consider, for example, using the intermediate good method to value irrigation. Ideally, analysts would compare the incomes of farmers if the irrigation project were built with the incomes of the same farmers if the project were not built. In practice, if the project is built, analysts cannot directly observe what the farmers' incomes would have been if it had not been built. One way to infer what their incomes would have been without the project is to use the incomes of the same farmers before the project was built (a before and after design) or the incomes of similar farmers who did not benefit from an irrigation project (a nonexperimental comparison group design). The before and after design is reasonable only if all other variables that affect farmers' incomes remain constant, such as weather conditions, crop choices, taxes, and subsidies. If these variables change, then the incomes observed before the project may not be good estimates of what incomes would have been if the project had not been implemented. Similarly, the comparison group design is appropriate only if the comparison group is similar in all important respects to the farmers with irrigation, except for the presence of irrigation.

As mentioned in Exhibit 14-2, salary differences between those with a college degree and those with a high school degree may depend on ability, intelligence, socioeconomic background, and other factors in addition to college attendance. Similarly, in labor market studies of the value of life, differences in wages among jobs may depend on variations in status among jobs, the bargaining power of different unions or nonfatality accident risk in addition to fatality risk. In simple asset price studies, the price of a house typically depends on factors such as its distance from the central business district and size, as well as whether it has a view. Analysts should take account of all important explanatory variables. If a relevant explanatory variable is omitted from the model and if it is correlated with the included variable(s) of interest, then the estimated coefficients will be biased, as we discuss in Chapter 13.

Self-Selection Bias

Another potential problem is self-selection bias. Risk-seeking people tend to self-select themselves for dangerous jobs. Because they like to take risks they may be willing to accept lower salaries than other people in quite risky jobs. Consequently, we may observe only a relatively small wage premium for dangerous jobs. Because risk seekers are not representative of society as a whole, the observed wage differential may underestimate the amount that average members of society would be willing to pay to reduce risks and, hence, may lead to underestimation of the value of a statistical life.

The self-selection problem arises whenever different people attach different values to particular attributes. As another example, suppose we want to use differences in house prices to estimate a shadow price for noise. People who are not bothered much by noise, possibly because of hearing disabilities, naturally tend to move into noisy neighborhoods. As a result, the price differential between quiet houses and noisy houses may be quite small, which would lead to an underestimation of the shadow price of noise for the "average" person.

HEDONIC PRICING METHOD

The *hedonic pricing* method, sometimes called the *hedonic regression method,* offers a way to overcome the omitted variables problem and self-selection bias that arise in the relatively simple valuation methods discussed earlier. Most recent wage-risk studies for valuing a statistical life (also called labor market studies) apply the hedonic regression method. It can be used to value an attribute, or a change in an attribute, whenever its value is capitalized into the price of an asset, such as houses or salaries.

Hedonic Regression

Suppose, for example, that scenic views can be scaled from 1 to 10 and that we want to estimate the benefits of improving the (quality) "level" of scenic view in an area by one unit. We could estimate the relationship between individual house prices and the level of their scenic views. But we know that the market value of houses depends on other factors, such as the size of the lot, which is probably correlated with the quality of scenic view. We also suspect that people who live in houses with good scenic views tend to value scenic views more than other people. Consequently, we would have an omitted variables problem and self-selection bias.

The hedonic pricing method attempts to overcome both of these types of problems.[9] It consists of two steps. The first step estimates the relationship between the price of an asset and all of the *attributes* (characteristics) that affect its value.[10] From this it derives the marginal effect of an attribute (e.g., a better scenic view) on the value of the asset, while controlling for other variables that affect the value of the asset. The second step estimates the WTP for the attribute, after controlling for "tastes," which are usually proxied by socioeconomic factors. From this information, we can calculate the change in consumer surplus resulting from projects that improve or worsen the attribute.

Suppose we are interested in determining the hedonic price of a scenic view. The first step estimates the relationship between the price of a house, P, and all of its attributes, such as the quality of its scenic view, $VIEW$, its distance from the central business district, CBD, its lot size, $SIZE$, and various characteristics of its neighborhood, $NBHD$, such as school quality. A model of the factors affecting house prices can be written as follows:

$$P = f(CBD, SIZE, VIEW, NBHD) \quad \textbf{(14.2)}$$

This equation is called a *hedonic price function* or *implicit price function.*[11] The change in the price of a house that results from a unit change in a particular attribute (i.e., the slope) is called the *hedonic price, implicit price,* or *rent differential* of the attribute. In a well-functioning market, the hedonic price can naturally be interpreted as the additional cost of purchasing a house that is marginally better in terms of a particular attribute. For example, the hedonic price of scenic views, which we denote as r_v, measures the additional cost of buying a house with a slightly better (higher-level) scenic view.[12] Sometimes hedonic prices are referred to as *marginal hedonic prices* or *marginal implicit prices.* Although these terms are technically more correct, we will not use them in order to make the explanation as easy to follow as possible.

Usually analysts assume the hedonic price function has a multiplicative functional form, which implies that house prices increase as the level of scenic view increases but at a decreasing rate. Assuming the hedonic pricing model represented in equation (14.2) has a multiplicative functional form, we can write:

$$P = \beta_0 CBD^{\beta_1} SIZE^{\beta_2} VIEW^{\beta_3} NBHD^{\beta_4} e^{\epsilon} \qquad \textbf{(14.3)}$$

The parameters, β_1, β_2, β_3, and β_4, are elasticities: they measure the proportional change in house prices that results from a proportional change in the associated attribute.[13] We expect $\beta_1 < 0$ because house prices decline with distance to the *CBD,* but β_2, β_3, and $\beta_4 > 0$ because house prices increase with increases in *SIZE, VIEW,* and *NBHD.*

The hedonic price of a particular attribute is the slope of equation (14.2) with respect to that attribute. In principle, it may be a function of all of the variables in the hedonic price equation.[14] For the multiplicative model in equation (14.3), the hedonic price of scenic views, r_v, is:[15]

$$r_v = \beta_3 \frac{P}{VIEW} > 0 \qquad \textbf{(14.4)}$$

In this model, the hedonic price of scenic views depends on the value of the parameter β_3, the price of the house, and the view from the house. Thus, it varies from one observation (house) to another. Note that plotting this hedonic price against the level of scenic view provides a downward-sloping curve, which implies that the marginal value of scenic views declines as the level of the view increases.

The preceding points are illustrated in Figure 14-3. The top panel shows an illustrative hedonic price function with house prices increasing at a decreasing rate as the level of scenic view increases. The slope of this curve, which equals the hedonic price of scenic views, decreases as the level of the scenic view increases. The bottom panel shows more precisely the relationship between the hedonic price of scenic views (the slope of the curve in the top panel) and the level of scenic view.

In a well-functioning market, utility-maximizing households will purchase houses so that their WTP for a marginal increase in each attribute equals its hedonic price. Consequently, in equilibrium, the hedonic price of an attribute can be interpreted as the willingness of households to pay for a marginal increase in that attribute. The graph of the hedonic price of scenic views, r_v, against the level of scenic view is shown in the lower panel of Figure 14-3. Assuming all households have identical incomes and tastes, this curve can be interpreted as a household inverse demand curve for scenic views.

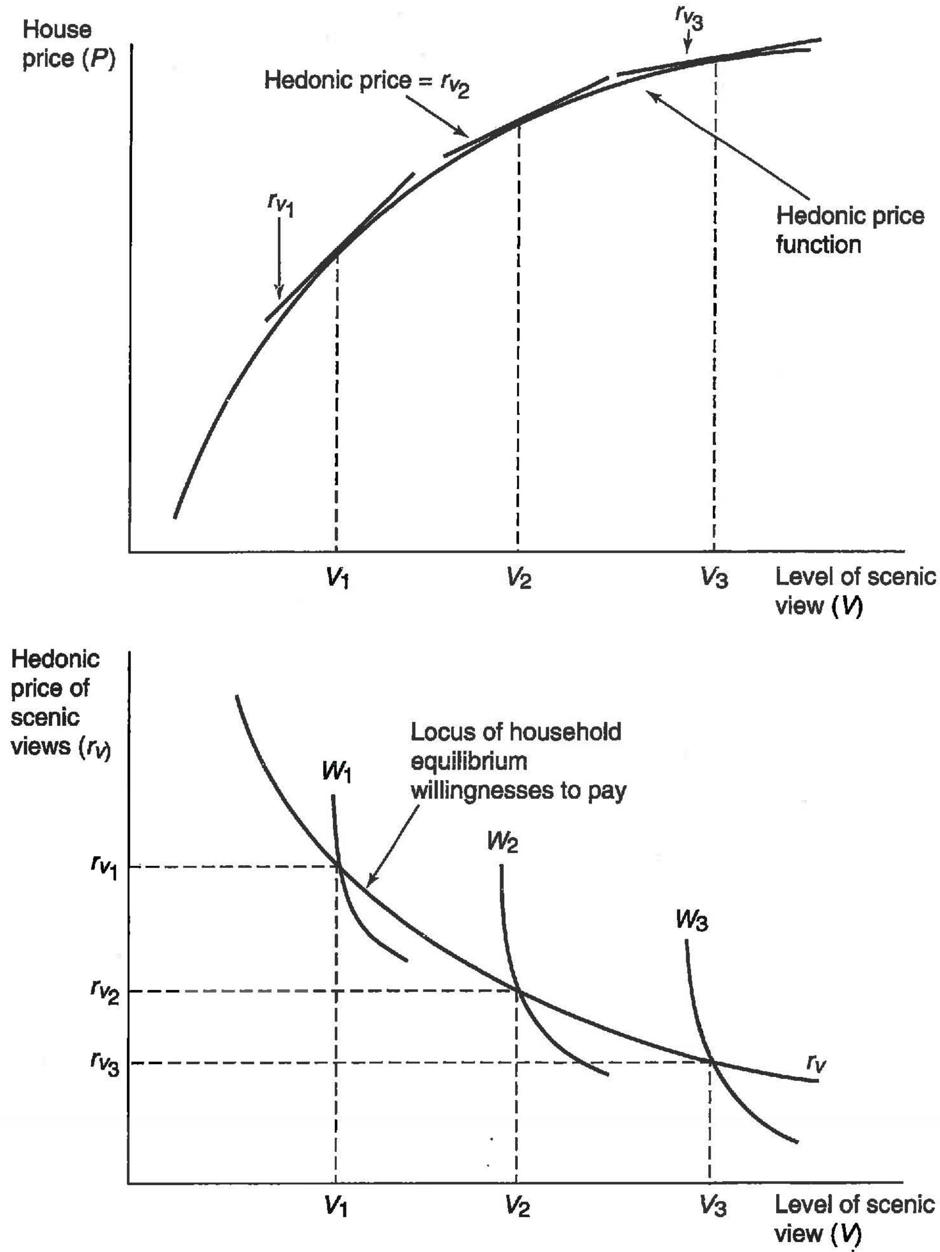

FIGURE 14-3 The Hedonic Price Method

Yet, households differ in their incomes and taste. Some are willing to pay a considerable amount of money for a scenic view; others are not. This brings us to the second step of the hedonic pricing method. To account for different incomes and tastes, analysts estimate the following willingness-to-pay (inverse demand) function for scenic views:[16]

$$r_v = W(VIEW, Y, Z) \tag{14.5}$$

where r_v is estimated from equation (14.4), Y is household income, and Z is a vector of household characteristics that reflects tastes (e.g., socioeconomic background, race, age, and family size). Three willingness-to-pay functions, denoted W_1, W_2, and W_3, for three different households are drawn in the lower panel of Figure 14-3.[17] Equilibria occur where these functions intersect the r_v function. When incomes and socioeconomic characteristics differ, the r_v function is the locus of household equilibrium willingnesses to pay for scenic views.

Using the methods described in Chapters 3 and 4, it is straightforward to use equation (14.5) to calculate the change in consumer surplus to a household due to a change in the level of scenic view. These changes in individual household consumer surplus can be aggregated across all households to obtain the total change in consumer surplus.

Using Hedonic Models to Determine the VSL

As we mentioned above, the simple consumer purchase and labor market studies that we described previously may result in biased estimates of the value of a statistical life due to omitted variables. For example, labor market studies that focus on *fatality risk* (the risk of death) often omit potentially relevant variables such as *injury risk* (the risk of nonfatal injury). This problem may be reduced by using the hedonic pricing method and, for example, estimating the following nonlinear regression model:[18]

$$\begin{aligned}\ln(\text{wage rate}) = \beta_0 &+ \beta_1\ln(\text{fatality risk}) + \beta_2\ln(\text{injury risk}) + \beta_3\ln(\text{job tenure}) \\ &+ \beta_4\ln(\text{education}) + \beta_5\ln(\text{age}) + \epsilon \qquad \textbf{(14.6)}\end{aligned}$$

The inclusion of injury risk, job tenure, education, and age in the model controls for variables that affect wages and would bias the estimated coefficient of β_1 if they were excluded. Using the procedure demonstrated in the preceding section, the analyst can convert the estimate of β_1 to a hedonic price of fatality risk and then estimate individuals' WTP to avoid fatal risks, thereby controlling for self-selection problems. Most of the empirical estimates of the value of life that are reported in Chapter 16 are obtained from labor market and consumer product studies that employ models similar or analogous to the one described here.

Problems with Hedonic Models

In theory, the hedonic pricing method can be used to determine the shadow price of many goods that are not traded in well-developed markets, such as externalities and public goods.[19] It helps to overcome omitted variable and self-selection problems. However, it does not overcome all problems. Here we mention six problems.

First, people must know and understand the full implications of the externality or public good. For example, in order to use the hedonic pricing method to value pollution, families should know, prior to the purchase of their house, the level of pollution to which it is exposed and should also know the effect of different pollution levels on their health. Similarly, in hedonic wage-risk studies, workers must correctly perceive the actual risks. W. P. Jennings and A. Kinderman observe that the rate of occupational fatalities in most industries has fallen roughly 95 percent since 1920 and is now one-third of

EXHIBIT 14-3

Dean Uyeno, Stanley Hamilton, and Andrew Biggs used the hedonic pricing method to estimate the cost of airport noise in Vancouver, Canada. They estimated the following hedonic price equation:

$$\ln H = \beta_0 + \beta_1 \text{NEF} + \sum_{j=2}^{k} \beta_k \ln X_j + \epsilon$$

where $\ln H$ is the natural log of residential property value, NEF is a measure of noise level (ambient noise levels are in the NEF 15–25 range, "some" to "much" annoyance occurs in the NEF 25–40 range, and "considerable" annoyance occurs above NEFs of 40), the X_j are house characteristics ($j = 2, \ldots, k$), and is an error term.

Their results show that Vancouver International Airport generates noise costs that capitalize into residential house and condominium prices. The estimated coefficient of the noise variable implies that detached houses very close to the airport with NEFs of 40 are 9.75 percent cheaper than houses far from the airport with NEFs of 25.

The estimated noise depreciation sensitivity is broadly consistent with previous studies, leading the authors to conclude that "the similarity of results spanning several decades and several Western countries would seem to suggest a broad and long-lived consensus on the issue (of the impact of airport noise on property values) . . ." (p. 14). In aggregate, the social cost of noise from Vancouver International Airport amounts to about $15 million in 1987 Canadian dollars.

Source: Adapted from Dean Uyeno, Stanley W. Hamilton, and Andrew J. G. Biggs, "Density of Residential Land Use and the Impact of Airport Noise," *Journal of Transport Economics and Policy* 27(1) 1993, 3–18.

the rate of accidental deaths in the home.[20] They argue that "the current fatality rates are so low and their individual causes so often random that statistical attempts to measure how fatalities affect wages are unlikely to meet with success." Second, it is important that the hedonic equations, such as equation (14.3) or equation (14.6), include correctly measured variables, as opposed to more readily obtainable but incorrect proxies. For example, house values may depend on the quality of construction. As this variable is difficult to determine without inspection, the researcher may use the year of construction as a proxy for quality. In econometrics, this problem is referred to as the *errors in variables* problem. Third, if the hedonic pricing model is linear, then the hedonic price of each attribute is constant, which would make it impossible to estimate the inverse demand function, such as equation (14.5).[21] Fourth, the market should contain many different houses so that families can find an optimal "package," that is, a house with just the right combination of attributes. In other words, there should be sufficient variety so that families can find a house that permits them to reach an equilibrium. This would be a problem if, for example, a family wanted a small, pollution-free house, but all of the houses in pollution-free areas were large. Fifth, there may be multicollinearity problems in the data. To use the same example, if expensive houses were large and located mainly in areas free of pollution, but inexpensive houses were small and located mainly in polluted areas, it would be difficult to estimate separate hedonic prices for pollution and size. Sixth, the method assumes that market prices adjust immediately to changes in attributes and in all other factors that affect demand or supply.

TRAVEL COST METHOD[22]

Most applications of the travel cost method (TCM) have been to value recreational sites. If the "market" for visits to a particular site is geographically extensive, then visitors from different origins bear different travel costs depending on their proximity to the site. The resulting differences in total cost, and the differences in the rates of visits that they induce, provide a basis for estimating a demand curve for the site.

Suppose that we want to estimate the value of a particular recreational site. We expect that the quantity of visits demanded by an individual, q, depends on its price, p, the price of substitutes, p_s, the person's income, Y, and variables that reflect the person's tastes, Z:

$$q = f(p, p_s, Y, Z) \tag{14.7}$$

The clever insight of the TCM is that although admission fees are usually the same for all persons (indeed, they are often zero), the total cost faced by each person varies because of differences in travel costs. Consequently, usage also varies, thereby allowing researchers to make inferences about the demand curve for the site.

The *full price* paid by visitors to a recreational site includes the opportunity cost of time spent traveling, the operating cost of vehicles used to travel, the cost of accommodations for overnight stays while traveling or visiting, parking fees at the site, and the cost of admission. The sum of all of these costs gives the total cost of a visit to the site. *This total cost is used as an explanatory variable in place of the admission price in a model similar to equation (14.7).*

Estimating such a model is conceptually straightforward. First, select a random sample of households within the market area of the site. These are the potential visitors. Second, survey these households to determine their numbers of visits to the site over some period of time, their costs involved in visiting the site, their costs of visiting substitute sites, their incomes, and their other characteristics that may affect their demand. Third, specify a functional form for the demand schedule and estimate it using the survey data. For an application of the TCM see Exhibit 14-4.

It is important to emphasize that when total cost replaces price in equation (14.7), this equation is not the usual demand curve that gives visits as a function of the price of admission. However, as we show next, such models can be used to derive the usual market demand curve and to estimate the average WTP for a visit.

Zonal Travel Cost Method

With the *zonal travel cost method*, researchers survey actual visitors at a site rather than potential visitors. This is often more feasible and less expensive than surveying potential visitors. Also, the level of analysis shifts from the individual (or household) to the area, or zone, of origin of visitors, hence the name *zonal travel cost method.*

The zonal TCM requires the analyst to specify the zones from which users of the site originate. Zones are easily formed by drawing concentric rings or iso-time lines around the site on a map. Ideally, households within a zone should face similar travel costs as well as have similar values of the other variables that would be included in an individual demand function, including similar prices of substitutes, similar incomes, and

EXHIBIT 14-4

Kerry Smith and William Desvousges used the travel cost method to estimate the average household value of a trip to recreational sites along the Monongahela River and the average household value of improving water quality. Their estimates of travel costs assumed the marginal cost of operating an automobile was \$0.08 per mile in 1976. For the time cost component of travel cost, they set the value of time equal to the wage rate in a person's particular occupation, which ranged from \$2.75 per hour for female farmers to \$7.89 per hour for male professional, technical, and kindred workers in 1977 dollars. Smith and Desvousges estimated many models including the following relatively simple travel cost model (t-statistics in parentheses):

$$\begin{array}{lllll} \ln V = -3.928 & -\ 0.051TC & +\ 0.00001Y & +\ 0.058DO & (R^2 = 0.225) \\ \quad (-3.075) & (-2.846) & (1.109) & (3.917) & \end{array}$$

where V is the number of site visits, Y denotes income, and DO is the percent saturation of dissolved oxygen in the water. Based on this model, the authors estimated that the average annual value of improving the water quality from boatable to game fishing would be \$7.16 in 1981 dollars (about \$15 in 2004 dollars), and the average annual value of improving the water quality from boatable to swimming would be \$28.86 in 1981 dollars (about \$60 in 2004 dollars).

Source: Adapted from V. Kerry Smith and William H. Desvousges, *Measuring Water Quality Benefits* (Boston: Kluwer Nijhoff Publishing, 1986), especially pp. 270–271.

similar tastes. If residents from different regions within a zone have quite different travel costs, then the zones should be redrawn. In practice, analysts often use local government jurisdictions as the zones because they facilitate the collection of data.

Assuming a constant elasticity functional form leads to the following model:

$$\ln\left(\frac{V}{POP}\right) = \beta_0 + \beta_1 \ln\bar{p} + \beta_2 \ln\bar{p}_s + \beta_4\bar{Y} + \beta_5\bar{Z} + \epsilon \qquad \textbf{(14.8)}$$

where V is the number of visits from a zone per period; POP is the population of the zone; and $\bar{p}$, $\bar{p}_s$, $\bar{Y}$, and $\bar{Z}$ denote the average values of p, p_s, Y, and Z in each zone, respectively. Again, when this equation is estimated, total cost replaces price.

Note that the quantity demanded is expressed as a visit rate. An alternative specification is to estimate the quantity demanded in terms of the number of visits, V, but to include population, POP, on the right-hand side of the regression equation. Although both specifications are plausible, the specification in equation (14.8) is less likely to involve heteroscedasticity problems (which we discuss in Chapter 13) and is, therefore, more likely to be appropriately estimated by OLS.

Using estimates of the parameters of equation (14.8), it is possible to estimate the change in consumer surplus associated with a change in the admission price to a site, the total consumer surplus associated with the site at its current admission fee, and the average consumer surplus per visit to the site. We illustrate how to do this using an example for a hypothetical recreational wilderness area, using the data presented in the first five columns of Table 14-1. This illustration assumes there are only five relevant

TABLE 14-1 Illustration of the Travel Cost Method

Zone	*Travel Time (hours)*	*Travel Distance (km)*	*Average Total Cost per Person ($)*	*Average Number of Visits per Person*	*Consumer Surplus per Person*	*Consumer Surplus per Zone ($ thousands)*	*Trips per Zone (thousands)*
A	0.5	2	20	15	525	5,250	150
B	1.0	30	30	13	390	3,900	130
C	2.0	90	65	6	75	1,500	120
D	3.0	140	80	3	15	150	30
E	3.5	150	90	1	0	0	10
Total						10,800	440

zones from which people travel to the recreational site. To avoid unnecessary complications, we assume that demand depends directly only on total price, not on income, the prices of substitutes, or any other variable.

In this example, the value of time for residents from different zones varies due to different income levels in different zones, as well as different travel times. Zone A is adjacent to the recreational area. Residents from zone A can, on average, pack up their equipment, drive to the site, park, and walk to the entrance in approximately one-half hour. Assuming the opportunity cost of their time is $9.40/hr and marginal vehicle operating costs are 15 cents/km, their total travel cost is $10 per round trip. Adding the admission fee of $10 per day yields a total cost of $20 per visit. Local residents make 15 visits each year, on average. Zone B is about 30 km away, requiring two hours of total travel time (including driving, parking, walking, and loading and unloading vehicles) for a round trip. Assuming the value of time for these residents is $5.50/hr and they travel individually, their total cost per visit is $30. Zone B residents make 13 visits per year on average. Zone C is about 90 km away and requires two hours of travel time in each direction. Assuming the value of these residents' time is $10.35/hr on average, and that their travel costs are shared between two people, the total cost per person is approximately $65 per visit. Zone C residents make six visits per year on average. Zone D residents live on the other side of the metropolitan area and, on average, make three visits each year. Assuming that their average wage rate is $8/hr and that two persons travel per vehicle, their per-person cost is $80 per visit. Zone E residents have to cross an international border. Though the distance is only slightly farther than from zone D, it takes almost one-half hour to get through customs and immigration. The average zone E wage is $8/hour. Assuming two persons per vehicle, the per-person cost is $90 per visit. On average, visitors from zone E make only one visit per year.

The data for average total cost per person visit (TC) and average visits per person (V), which are in columns 4 and 5 of Table 14-1, are represented graphically in Figure 14-4. The equation $TC = 95–5V$ fits these data perfectly. (In practice, ordinary least squares would be used to fit a line to data points that would not all lie exactly on the line.) This equation is the "representative" individual's inverse demand curve: it shows how much a typical visitor is willing to pay for a visit to the recreational area (specifically, $90 for the first visit, $85 for the second visit, . . . , $20 for the fifteenth visit).

Different individuals face different prices (costs) for their visits depending on their zone of origin. It is cheaper for those who live closer. Therefore, individuals' consumer surplus varies according to their zone of origin. The consumer surplus for a particular visit from a particular zone equals the difference between how much someone is willing to pay for that visit, given by the point on the "representative" individual's inverse demand curve, and how much the person actually pays for a visit *from that zone.* As mentioned previously, "representative" visitors are willing to pay $90 for their first visit, $85 for the second, . . . $65 for their sixth. People from zone C actually pay only $65 for each visit. Consequently, their consumer surplus equals $25 for the first visit, $20 for the second visit, $15 for the third visit, $10 for the fourth visit, $5 for the fifth visit, and $0 for the sixth visit.

The total consumer surplus for someone from zone C is obtained by summing the consumer surpluses associated with each visit across all visits, which amounts to $75. This amount is represented by the area of the shaded triangle in Figure 14-4.[23] Similarly, the consumer surplus is $525 per person for residents of zone A, $390 for residents of zone B, $15 for residents of zone D, and $0 for residents of zone E. These amounts are presented in the sixth column of Table 14-1. Clearly, people who live closer to the recreational site enjoy more consumer surplus from it than people who live farther away.

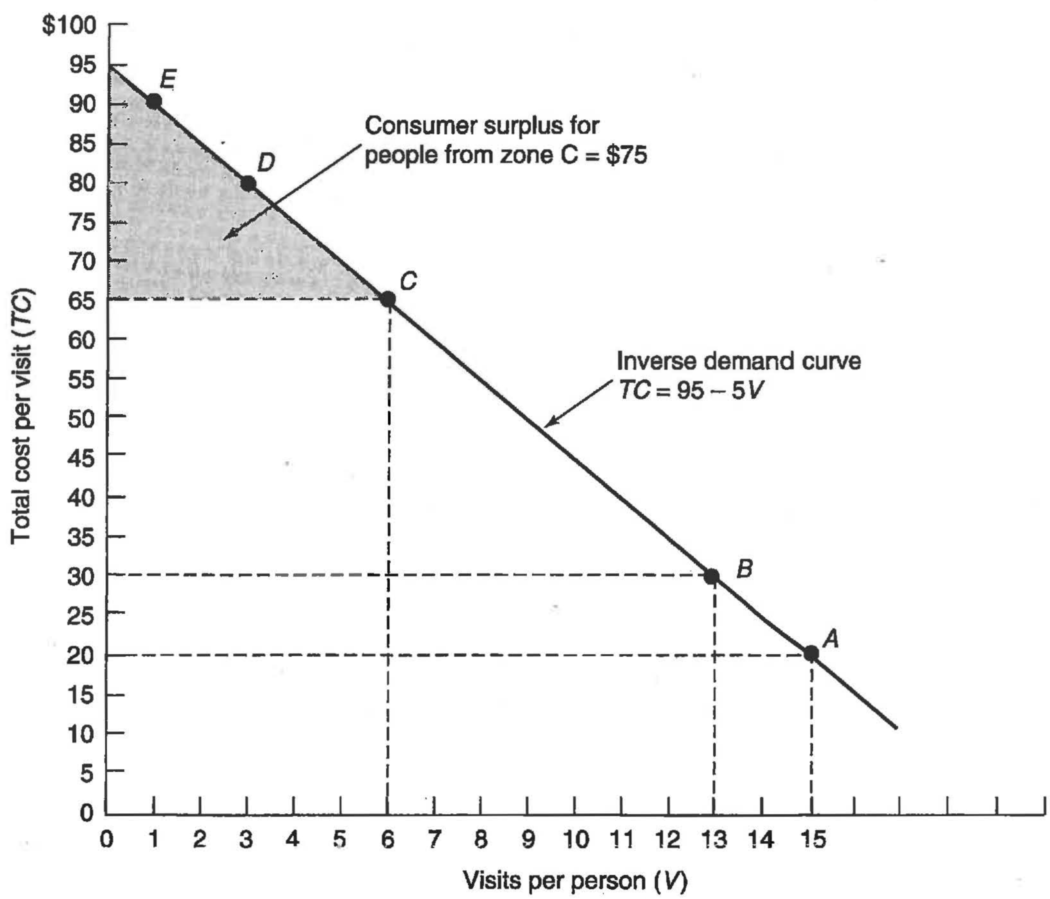

FIGURE 14-4 "Representative" Individual's Inverse Demand Curve for Visits to a Recreational Area as a Function of Total Cost per Visit

From this information and knowledge of the populations of each zone, we can calculate the total consumer surplus per year and the average consumer surplus per visit for the site. Suppose zones A, B, D, and E have populations of 10,000 people, while zone C has a population of 20,000 people. The consumer surplus per zone is obtained by multiplying the consumer surplus per person in a zone by the population of that zone, as shown in the fifth column in Table 14-1. Adding across all zones yields the total annual consumer surplus for the site of \$10.8 million. Adding admission fees of \$4.4 million indicates that the annual (gross) benefit of the site to all visitors equals \$15.2 million. If the government decided to use the site for some completely different purpose, such as logging, this would be a measure of the lost annual benefits.

The total number of visits to the recreational area is 440,000, as shown in the last column of Table 14-1. Dividing the total consumer surplus by the total number of visits gives an average consumer surplus per visit of \$24.55. If we now add the admission fee of \$10, then we obtain the *average demand price* per visit, which is the average maximum amount a visitor would pay for a visit to the site. In this example, the average demand price is \$34.55.

Estimating the Market Demand Curve for a Public Good Using the Zonal Travel Cost Method

It is possible to construct the *market demand curve* for a public good from estimation of equation (14.8) where price is replaced with total cost. That is, we can derive an expression in which the admission fee is a function of the *total* number of visits to the site. This curve can then be used to estimate total consumer surplus in the usual way. Unfortunately, because each point on the demand curve has to be estimated separately, precise computation is not straightforward.

For illustrative purposes, we continue with the previous example where $TC = 95 - 5V$. To begin, we know two points on the market demand curve. At an admission price of \$10, the current admission fee, there are 440,000 visits, represented by point *c* in Figure 14-5. Now consider how high admission fees can be raised until demand is choked off (equals zero). We know from the representative individual's inverse demand curve ($TC = 95 - 5V$) that the maximum WTP (including all costs) is \$95. Subtracting the travel cost of users from zone A (who have the lowest travel cost) implies that the maximum WTP for admission is \$95 − \$10 = \$85. This is the intercept (choke price) of the inverse market demand curve and is represented by point ***a*** in Figure 14-5.

We can find other points on the market demand curve by assuming that the admission fee is increased or decreased and then predicting the visit rate from each zone at the new price. Suppose, for example, the admission fee were raised from \$10 to \$20, so that *TC* increased by \$10 dollars. Because the *individual* demand curve can be written as $V = 19 - 0.2TC$ (the inverse of $TC = 95 - 5V$), a \$10 increase in *TC* would reduce the number of visits per person by two. Thus, if the admission price were \$20, then the predicted number of visits would be 13 for zone A, 11 for zone B, 4 for zone C, 1 for zone D, and −1 for zone E. Because negative visits are not possible, we set the number of visits per person for zone E to zero. The total number of visits demanded at the new price is computed by multiplying the predicted visit rate for each zone by its

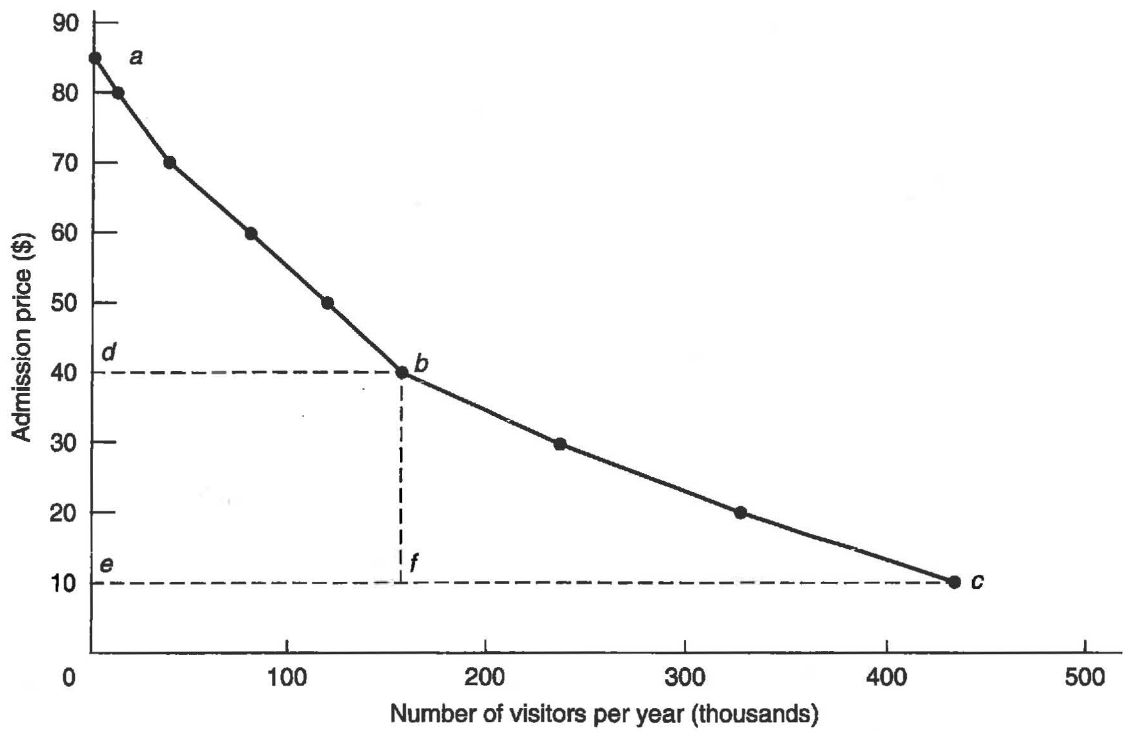

FIGURE 14-5 The Market Demand Curve for a Recreational Site Derived Using the Zonal Travel Cost Method

population and summing these products (13 × 10,000 + 11 × 10,000 + 4 × 20,000 + 1 × 10,000 = 330,000). Thus, at a price of $20 we would expect 330,000 visits. This is a third point on the market demand curve.

With a sufficient number of points, the market demand curve can be sketched to any desired level of accuracy. The market demand curve in Figure 14-5 is computed on the basis of $10 price increments. The annual consumer surplus for the site is the area between the curve and the current admission fee from zero visits to 440,000 visits. Assuming for simplicity that the demand curve is linear between points *a* and *b,* and between points *b* and *c,* we estimate the annual consumer surplus of the site equals $12.6 million, and the annual (gross) benefit of the site equals $17.0 million.[24] Due to the linear approximation and the relatively few points on the demand curve, we slightly overestimate the benefits.

Limitations of the TCM

The usefulness of the TCM is limited in a number of ways. One limitation is that the TCM provides an estimate of the WTP for the entire site rather than for specific features of a site. As we often wish to value changes in specific features of a site (e.g., improvements in the hiking trails), the basic TCM does not provide the needed information. However, if the residents of zones can choose from among a number of alternative recreational sites with different attributes, then it may be possible to use the *hedonic travel cost method* to find attribute prices.[25] This method treats the total cost of visiting a particular site from a particular zone as a function of both the distance from that zone to the site and various attributes of the site. Its application raises a number of issues beyond those previously discussed in the context of the basic hedonic pricing model. Therefore, before attempting to apply the hedonic travel cost method, we recommend consulting other sources.[26]

Measuring the cost of a visit to the site may be difficult.[27] Perhaps the most obvious problem is the estimation of the opportunity cost of travel time, which we have previously discussed.[28] Even defining and measuring travel costs raises some difficult issues. Some analysts include the time spent at the site, as well as the time spent traveling to and from it, as components of total price. If people from different zones spend the same amount of time at the site, and if the opportunity cost of their time is similar, then it does not matter whether the time spent at the site is included or not—both the height of the demand curve and total price shift by the same amount for each consumer so that estimates of consumer surplus remain unchanged. If, however, people from different zones have different opportunity costs for their time, or if they spend different amounts of time at the site, then including the cost of time spent at the site would change the price facing persons from different zones by different amounts and, thereby, change the slope of the estimated demand curve.

Another problem arises because recreation often requires investment in fairly specialized equipment such as tents, sleeping bags, wet-weather gear, canoes, fishing rods, and even vehicles. The marginal cost of using such equipment should be included in total price. Yet, estimating the marginal cost of using capital goods is usually difficult. As with time spent at the site, however, these costs can be reasonably ignored if they are approximately constant for visitors from different zones.

Multiple-purpose trips also pose an analytical problem. People may visit the recreational site in the morning and, for example, go river rafting nearby in the afternoon. Sometimes analysts exclude visitors with multiple purposes from the data. Including visitors with multiple purposes is usually desirable if costs can be appropriately apportioned to the site being valued. If the apportionment is arbitrary, however, then it may be better to exclude multiple users.

A similar problem results because the journey itself may have value. The previous discussion assumes implicitly that the trip is undertaken exclusively to get to the recreation site and travel has no benefit per se. If the journey itself is part of the reason for the visit to the site, then the trip has multiple purposes. Therefore, part of the cost of the trip should be attributed to the journey, not the visit to the recreation site. Not doing so would lead to overestimation of site benefits.

A more fundamental problem is that the travel cost variable may be endogenous, not exogenous. One neighborhood characteristic some people consider when making their residential choices is its proximity to a recreational area. People who expect to make many visits to a recreational area may select a particular neighborhood (zone) partially on account of the low travel time from that neighborhood to the recreational area. If so, the number of trips to a particular recreational area and the price of these trips will be determined simultaneously. Under these circumstances equation (14.8) may not be identified, a problem which we discuss in Chapter 13.[29]

Another econometric problem is that the dependent variable in the estimated models is *truncated*. Truncation arises because the sample is drawn from only those who visit the site, not from the larger population that includes people who never visit the site. Application of ordinary least squares to the truncated sample would result in biased coefficients. However, there are more complicated estimation methods that overcome this problem.

There may also be an omitted variables problem. If the price of substitute recreational sites varies across zones or if tastes for recreation varies across zones, then the estimated coefficients may be biased if the model does not control for these variables. As previously discussed, bias results when an excluded variable is correlated with an included variable.

Finally, derivation of the market demand curve assumes that people respond to changes in price regardless of its composition. Thus, for example, people respond to, say, a $5 increase in the admission price in the same way as a $5 increase in travel cost. This presumes that people have a good understanding of the impact of changes in the prices of fuel, tires, and repairs on their marginal travel cost.

DEFENSIVE EXPENDITURES METHOD[30]

If you live in a smoggy city, then you will probably find that your windows often need cleaning. If you hire someone to clean your windows periodically, the cost of this action in response to the smog is termed a *defensive expenditure*—it is an amount spent to mitigate or even eliminate the effect of a negative externality. Suppose the city passes an ordinance that reduces the level of smog so that your windows do not get as dirty. You would now have to spend less on window cleaners. The reduction in defensive expenditures—the defensive expenditures avoided—has been suggested as a measure of the benefits of the city ordinance. In other circumstances, the costs of a policy change might be measured by the increase in defensive expenditures.

This method is an example of a broad class of *production function methods.* In these methods, the level of a public good or externality (e.g., smog) and other goods (window cleaners) are inputs to some production process (window cleaning). If the level of the public good or externality changes, then the levels of the other inputs can be changed in the opposite direction and still allow the quantity of output produced to remain the same. For example, when the negative externality of smog is reduced, less labor is required to produce the same number of clean windows. The change in expenditures on the substitute input (window cleaners) is used as a measure of the benefit of reduction of the public good or externality.

Suppose that the demand curve for clean windows is represented by the curve labeled D in Figure 14-6. Let S_0 represent the marginal cost of cleaning windows initially, that is, prior to the new ordinance. The initial equilibrium price and quantity of clean windows are denoted by P_0 and Q_0, respectively. The effect of the new ordinance to restrict smog is to shift the marginal cost curve for clean windows down and to the right from S_0 to S_1: because there is less smog, windows are easier to clean, so more windows can be cleaned for the same price. At the new equilibrium, the price of clean windows is P_1 and the quantity of clean windows is Q_1. The change in consumer surplus is represented by the area of the trapezoid P_0abP_1.