CHAPTER

15 SHADOW PRICES FROM SECONDARY SOURCES

Policy analysts typically face time pressure and resource constraints. They naturally wish to do cost-benefit analysis with the least redundant effort, at the lowest opportunity cost, and without getting into estimation issues beyond their competence. Anything that legitimately lowers the cost of doing CBA increases the likelihood that any particular CBA will be worth doing. In order to assess either existing or proposed policies and projects, analysts require credible measures of the social values of their impacts. As we see in Chapters 4 and 12, when these impacts occur in efficient markets, their impacts can be estimated from changes in market prices and quantities. The expected social cost of labor for environmental projects, for example, can usually be directly derived from local labor markets. However, when there are market failures or there is no market at all (so-called missing markets), then analysts need a shadow price. In order to obtain such estimates, analysts might conduct their own valuation studies. As we discuss in Chapter 13, there are many possible approaches, but many of these methods are time consuming and resource intensive. The most straightforward, low-cost method is to use *existing estimated shadow prices,* or *plug-ins.* Using plug-ins in a CBA is known as *benefit transfer* or sometimes *information transfer.*

Most CBAs involve some impacts that can be valued at current market prices and other impacts that can be valued using plug-ins. Transportation and infrastructure project analysts, for example, can use market prices for construction resources (materials, land, labor, and equipment) and ongoing operational costs (labor and maintenance materials) but require plug-ins for the value of lives saved, injuries avoided, accidents avoided, time saved, air quality changes, and noise level changes, to name only some.[1]

At least two kinds of plug-ins can be found in the literature. First, and most importantly, are the estimates of shadow prices when markets are missing. Examples include the value of a unit of time, the value of a statistical life, or the (negative) value of particular types of crime. After necessary adjustments, such as the conversion to current dollars, previously estimated values of these impacts can be directly used in new CBAs. This is the major focus of this chapter.

Second, economists have estimated price elasticities of demand, cross-elasticities, and income elasticities for a range of specific goods. Many elasticities have been summarized in survey articles.[2] Recently, meta-analyses have become more common.[3] As CBA analysts are frequently dealing with long-lived projects, long-run elasticities are usually more relevant than short-run elasticities. These elasticities can be used to project the policy impacts of proposed projects as we discuss in Chapter 12. As they are based on the responses of people to similar price changes in the past, they provide an empirically grounded basis for predicting the responses to proposed price changes. For example, how consumers responded to a price increase for water in New Mexico can be reasonably used to estimate how they will respond to a similar price increase in Arizona. In addition to own-price elasticities, estimates of cross-price elasticities, which identify changes in the demand for a good that are likely to result from changes in the prices of other goods, though less often available, are frequently very useful. For example, are transportation and various forms of communications (such as telecommuting and teleconferencing) complements or substitutes?[4] These cross-elasticities are important to transport planners and policy analysts who are estimating the costs and benefits of transport capital investments, assessing expected consumers' responses to price changes, or forecasting changes in demand for transportation. Existing estimates of income elasticities can also be very useful, especially when policies have strong distributional effects. Elasticity estimates are scattered widely throughout the academic literature, usually in the topic-specific journals. Therefore, analysts must garner them from the relevant economic and policy journals on an ongoing basis.

This chapter briefly surveys the relevant literature and provides a "best estimate" of the value of each impact. It focuses on impacts that occur in many CBAs: the value of life, the cost of various kinds of injuries (including those resulting from road crashes), the cost of crime, and the value of time.[5] We also review per-unit values of air pollution, water pollution, and recreational activities, and we briefly discuss empirical estimates of the marginal excess tax burden.

The plug-ins are summarized in Tables 15.1 through 15.6. In order to facilitate comparability and for ease of use, plug-in values are usually expressed in 1999 U.S. dollars using the consumer price index deflator obtained from Table 6.3. The units of each impact are usually dollars per person or per event. Other values are reported in terms of units produced, such as "per ton." We also report the relevant time unit, such as "per day," "per year," and so on.

People have varying preferences. Consequently, when using our best estimates in a particular CBA, they should be adjusted to take account of the preferences and profile of the affected population. After providing the plug-ins, we briefly address some of the information transfer issues related to adjusting plug-ins to new CBAs.

THE VALUE OF LIFE

Researchers have used several benefit estimation techniques to estimate the value of life. These techniques either indirectly estimate the "price" people must be paid to be willing to take, or accept, certain risks by observing their behaviors in markets for commodities that embody risks (Chapter 13), or directly elicit these amounts with hypothetical survey questions (Chapter 14). The most common and widely accepted of the market-based techniques are those that examine how much of a wage premium people working in risky jobs must be given to compensate them for the additional risks. Our purpose here is not to revisit methodological issues but to summarize the empirical estimates of the value of statistical life in the United States. We draw primarily on overviews of the evidence provided by Ted Miller, by Ann Fisher, Lauraine Chestnut, and Daniel Violette, and by W. Kip Viscusi.[6]

The Miller Survey of Value-of-Life Estimates

Ted Miller reviews 49 studies that estimated the value of life using criteria such as the quality of the survey design, sample size, and inclusion of appropriate risk variables. He then summarizes the value-of-life estimates from the 29 studies that best satisfied these criteria. All of Miller's estimates are in 1985 after-tax dollars and are computed with a consistent real discount rate of 2.5 percent.

The studies estimate the value of life in one of four ways based on (1) wage premia for risky jobs; (2) consumers' willingness to pay for safety features (safer cars and smoke detectors), houses in less polluted areas, or life insurance; (3) individual behavior with respect to decisions concerning the use of pedestrian tunnels and seat belts, choice of speed when driving, and driver travel time; and (4) contingent valuation methods to survey individuals about their willingness to invest in specific ways to increase health and safety. Consistent with our conclusions in Chapter 14, the contingent valuation studies produce somewhat higher values. The mean value of life across the 29 studies is $3.02 million in 1999 dollars, with a standard deviation of 0.77 in 1999 dollars. Miller concludes that there is enough consistency across the studies to suggest that this mean is quite plausible. He points out that the evidence also suggests that individuals value life similarly whether the risk is largely voluntary (e.g., auto driving behavior) or involuntary (e.g., the risk of a nuclear accident) and whether the potential death is slow and painful or sudden and quick.

The Fisher, Chestnut, and Violette Survey of Value-of-Life Estimates

These authors review 21 studies reporting estimates of the value of life. They provide both the range for each estimate of the value of life from each study and a best estimate. Additionally, they also report an estimate of the mean level of risk considered in each study. Knowing the mean level of risk is useful because individuals' valuation of risk reduction (or safety increase) tends to increase with the level of risk, as discussed in Chapter 13.

The authors divide the 21 studies that they review into five categories: early low-range wage-risk estimates, early high-range wage-risk estimates, new wage-risk estimates, new contingent valuation studies, and consumer market studies. They conclude that the most defensible empirical results indicate the range for the value-per-statistical-life estimates is $2.43 million to $12.92 million (in 1999 dollars) but place more confidence in the lower end of the range.

The Viscusi Survey of Value-of-Life Estimates

W. Kip Viscusi provides the most extensive review of both the conceptual framework and the empirical literature on the value of life. Here we concentrate on his assessment of the empirical literature, which is reported in 1990 dollars. He reviews three sets of studies: those concerning wage premia for risky jobs, other revealed preference approaches, and surveys. Viscusi reports the empirical results of 24 labor market studies. He observes that the value of life is not a constant but reflects the wage-risk trade-off pertinent to the preferences of the workers in a particular sample. The majority of these estimates are in the range of $3.82 million to $8.92 million (in 1999 dollars).

Viscusi reviews seven revealed preference studies based on behavior other than labor market behavior. As he points out, these studies are probably somewhat less reliable than labor market studies because the latter allow one to distinguish risk levels across individuals, whereas other revealed preference methods do not. For example, we normally do not know whether individuals purchasing smoke detectors live in apartments that are "firetraps" or modern apartments with built-in sprinklers. Additionally, some of these studies can only provide information on the lower bound of the value of life because discrete purchase decisions do not force individuals to reveal their total willingness-to-pay, only whether they will pay more than a given price.[7] These studies provide widely varying estimates of the value of life from $0.09 million to $5.10 million (in 1999 dollars). However, he argues that the study that provides the most reliable estimate is Scott Atkinson and Robert Halvorsen's analysis of the purchase of safety features on new automobiles.[8] This study includes the car purchase price (equivalent to the wage in the labor studies) and explanatory variables such as other product characteristics, characteristics of the purchasers, and the risk. The study estimates the value of life at the top of the range for this group of studies.

Finally, Viscusi reviews six survey, or contingent valuation, estimates of the value of life that have a wide range of values—from $0.13 million to $19.1 million (in 1999 dollars).

Conclusion on the Value of Life

As Table 15.1 shows, we suggest a plausible range for the value of a statistical life saved is between $2.5 million and $4.0 million in 1999 dollars. Although primarily based on Miller, this range is also quite close to Fisher and colleagues' lower-bound estimate, in which these authors expressed greater confidence. The upper end of the range corresponds to Viscusi's lower-bound estimate, which is the one in which he expresses the greatest confidence.

TABLE 15.1 Plug-Ins for Value of Life and Injury Costs (in 1999 U.S. dollars)

Plug-In Category (impact)	***Shadow Price Value***	***Comments***
VALUE OF LIFE	$2.5 million to $4.0 million per life saved	Based primarily on Miller (1989). See also Fisher, Chestnut and Violette (1989) and Viscusi (1993). Should adjust for risk level if known.
MONETARY INJURY COSTS		
1) Eventually fatal	1) $491,000 per injured person	Based on Rice, MacKenzie, and associates (1989). Includes monetary costs only, not pain and suffering.
2) Hospitalized (nonfatal)	2) $53,000 per injured person	
3) Nonhospitalized (nonfatal)	3) $800 per injured person	
4) Average cost of an injury	4) $4,300 per injured person	
A) Motor vehicle injury	A) $14,000 per injured person	
B) Falls	B) $4,700 per injured person	
C) Firearm injuries	C) $83,300 per injured person	
D) Poisonings	D) $7,800 per injured person	
E) Fire injuries and burns	E) $4,000 per injured person	
F) Drownings and near-drownings	F) $100,600 per injured person	
G) Other	G) $1,800 per injured person	
COST OF WORK-RELATED INJURY		
1) Less serious	1) $31,000 per injured person	Based on Viscusi's (1993) survey of labor market studies; therefore, includes pain and suffering but not all social costs. Higher values involve loss of workdays.
2) More serious	2) $64,000 per injured person	
SOCIAL COST OF MOTOR VEHICLE CRASH INJURIES		
1) Spinal cord	1) $2,054,700 per victim (0.66)	Based on Miller's (1993) $2.8 million estimate of the value of life (in 1994 dollars). Attempts to measure total social cost, including pain and suffering. Numbers in parentheses measure cost as a fraction of the value of life.
2) Brain	2) $119,000 per victim (0.04)	
3) Lower extremity	3) $200,400 per victim (0.06)	
4) Upper extremity	4) $77,900 per victim (0.03)	
5) Trunk/abdomen	5) $59,400 per victim (0.02)	
6) Face, other head, or other neck	6) $22,900 per victim (0.01)	
7) Minor external	7) $5,500 per victim (0.002)	
A) Average for nonfatal crash	A) $56,200 per victim (0.02)	
B) Average for fatal crash	B) $3,358,900 per victim (1.08)	
MONETARY COST OF FIREARM INJURIES		
1) Eventually fatal	1) $578,400 per injured person	Based on Max and Rice (1993). Includes monetary costs only, not pain and suffering.
2) Hospitalized (nonfatal)	2) $51,400 per injured person	
3) Nonhospitalized (nonfatal)	3) $700 per injured person	

THE COST OF INJURIES

Table 15.1 also summarizes four sets of estimates for the cost of injuries in the United States, again updated to 1999 dollars. The first set of estimates, which is based on a major report prepared for Congress by Dorothy Rice, Ellen MacKenzie, and their associates, provides detailed estimates of costs for injuries from different causes and for three levels of severity.[9] The second set of estimates is based on a survey of labor market studies by V. Kip Viscusi that estimate the cost of injuries. The third set is based on Ted Miller's 1993 study of injury costs resulting from automobile crashes. The fourth set of estimates is based on Wendy Max and Dorothy Rice's study of the lifetime costs of firearm injuries.[10] We also discuss estimates of the cost of serious road injuries by the Transport Research Laboratory in the United Kingdom, although these are not summarized in Table 15.1.

The Rice-McKenzie and Associates' Estimates of the Cost of Injuries

The Rice-McKenzie estimates incorporate medical and rehabilitation costs and forgone earnings (including an imputed value for household labor) but, unfortunately, do not include pain and suffering and other dimensions of unhappiness that people would pay to avoid. They also do not include property damage losses and other related costs, such as court costs, as their study was only concerned with the monetary cost of injuries rather than with the social cost of any activity associated with the injury. Thus, the human capital approach adopted in the study leads to very conservative estimates of the social cost of injuries because it ignores disutility resulting from pain and suffering. (Methods for estimating this disutility are discussed in the section on using the market analogy method to value a life saved in Chapter 13 and in the discussion of quality-adjusted life-years in Chapter 17.) All estimates presented in Table 15.1 are updated to 1999 dollars and rounded.

The Viscusi Survey of Cost-of-Injury Estimates

W. Kip Viscusi has reviewed the evidence on the cost of nonfatal work-related injuries (in the same article as his value-of-life estimates, discussed earlier in this chapter). He computes cost-of-injury estimates from 14 labor market studies conducted between 1978 and 1991. These studies focus on individual willingness-to-pay; therefore, they include the disutility of pain and suffering. Unfortunately, the individual studies cover a wide range of nonfatal injury circumstances. For example, some studies only examine injuries that resulted in some degree of job interruption, whereas others include less serious injuries. Some studies use average injury risk rates for industries, whereas others use workers' (subjective) assessment of risk. Some studies control for wage differences due to loss-of-life risks, whereas others do not. Additionally, of course, mean injury risk rates vary considerably across the studies (from 0.03 to 0.10 per year). Because work-related injuries may be of different severity and type than other kinds of injuries, these estimates cannot be directly compared to estimates based on injuries in general. In Table 15.1, we divide these work-related injury estimates into a less serious estimate (item 1) and a more serious estimate (item 2).

The Miller Estimates of the Cost of Motor Vehicle Crashes

Reduced injuries and reduced automobile repair costs are common potential impacts of transportation projects, such as better road lighting, altered speed limits, or new vehicle safety features. Ted Miller has estimated the comprehensive costs of U.S. motor vehicle crashes.[11] The cost of motor vehicle crashes is not synonymous with the cost of injuries because motor vehicle crashes typically engender many costs, such as vehicle damage costs and additional time travel costs for other motorists, that the typical injury does not. Thus, one would expect the average cost of a motor vehicle crash to be higher than the average injury cost. Additionally, of course, vehicle crashes are also likely to have a distribution of injury severity that differs from the distribution of injuries from all causes.

Miller's cost estimates include medical and emergency services, lost wages and household production, workplace disruption, insurance administration costs, the cost of legal proceedings (but not the income transfers resulting from settlements), and the lost quality of life (including pain and suffering, which are inferred from individuals' willingness-to-pay to avoid injuries). Thus, these estimates differ methodologically from the cost-of-injury estimates calculated by Dorothy Rice and her colleagues, which only included "monetary" losses.

Miller first reports his estimates as a fully monetized "cost per crash" figure that can be directly plugged into a CBA. Nonfatal quality-of-life losses were calculated by first multiplying the value of fatal risk reduction by the ratio of the years of functional capacity lost through the injury to years lost in a fatality, and then subtracting the monetary component of this value, namely, the value of wages and household production that was lost due to the injury.

Miller also reports estimates quantitatively as years of life and functioning lost, which can be used in a cost-effectiveness ratio because they quantify but do not monetize the value of life or injuries. Thus, for example, crash injuries involving lower extremities, such as pelvis and hip, resulted in 6.5 years of functional loss, on average. This latter approach reflects the fact that some decision makers are uncomfortable monetizing the value of life or the cost of injuries. (Cost-effectiveness analysis is explained in detail in Chapter 17.)

Miller classifies crash injuries by region of the body in decreasing order of severity: spinal cord; brain; lower extremity; upper extremity; trunk/abdomen; other head, face, and other neck; and minor external. The summary findings by region of the body (rounded in 1999 dollars) are shown as items 1 through 7 in Table 15.1. He also simply divides injury costs into an average cost for nonfatal crashes and an average cost for fatal crashes (items A and B, respectively, in Table 15.1).

Miller points out that not using comprehensive cost measures (i.e., measuring incorrectly) can seriously distort public policy decision making. If injury costs are underestimated, then the benefits of safety-enhancing road improvements are lowered relative to the benefits of time-saving road improvements. It may, thus, appear that it is better to be dead than to be stuck in traffic![12] This is usually not the case when the numbers are estimated correctly.

The Max and Rice Cost of Firearm Injuries

Wendy Max and Dorothy Rice provide estimates of the cost of firearm injuries. We report these estimates here rather than under the cost-of-crime estimates because many firearm injuries are accidental. Their estimate of costs has two components: (1) direct costs such as medical and hospital, rehabilitation, medication, and transportation costs; (2) indirect costs resulting from lost productivity (including the value of household labor). Indirect costs include morbidity costs (estimated as the value of days lost from injury or as the years of life lost from injury-related disability) and mortality costs (estimated as either the monetary value of lost future output or the years of life lost from premature death).

The estimates are for three classes of firearm injury: those resulting in fatalities, those resulting in hospitalization, and those not requiring hospitalization. It is important to note that their method is likely to produce very conservative estimates of the cost of firearm injuries because they do not include psychological costs of injuries (which one would expect to be an important component of total individual costs) and they use forgone earnings (rather than willingness-to-pay) in estimating the (lost) value of life.

Max and Rice estimates of the average total cost per injured person for firearm injuries are shown in Table 15.1. They also found that fatal injuries resulted in an average decrease in life of 35.7 years per injured person, nonfatal injuries that required hospitalization reduced the average longevity of the injured person by 2.87 years, whereas injuries that did not require hospitalization led to a 0.01-year reduction.

The Transport Research Laboratory Estimate of the Cost of Serious Road Injuries

In 1989, the United Kingdom Department of Transport commissioned a number of studies of the cost of serious road accidents. These studies adopted a *WTP* approach.[13] Two random samples of households were drawn: one using standard contingent valuation procedures and the other using "standard gamble" questions. The contingent valuation questions asked respondents how much they would be willing to pay for a hypothetical safety feature that would reduce the risk of given injuries by a specific amount and that had to be purchased annually.

In the standard gamble format, respondents were asked to suppose that they had suffered a road injury, which, if treated in the standard way, would have a given prognosis. They were then asked to suppose that an alternative treatment would return them to normal health if successful—a result that is better than that produced by the standard treatment—but which, if unsuccessful, would result in a prognosis worse than that associated with the standard treatment. As described in Chapter 17, the purpose of such questions is to determine the risk of treatment failure at which they would be indifferent between accepting and rejecting the treatment.

The researchers found that the contingent valuation questions produced estimates that were between 1.5 and 10.5 times higher than the standard gamble method. They conclude that, in this case, the standard gamble estimates are superior.[14] As a result of this work, the U.K. Department of Transport established a figure of £74,480 (in 1992 pounds) for the cost of a "serious" nonfatal road accident including all economic costs, which is about $145,000 in 1999 dollars.

Conclusion on Cost of Injuries

The Rice and MacKenzie estimates are least useful for injuries that eventually prove fatal, as monetary costs are likely to be only a small fraction of total social costs. However, their estimate of the cost of hospitalization for injuries is not much lower than Viscusi's upper-bound estimate in equivalent-year dollars.

In Table 15.1, motor vehicle crash injury costs are reported in dollars and as a fraction of the value of life. This illustrates the alternative method of reporting injury costs. The 1.08 coefficient for fatal crashes indicates that if a relatively conservative estimate of the value of life is used (in this case Miller's value of life), motor vehicle crashes resulting in death can produce costs that are higher than "average" value-of-life estimates.

THE COST OF CRIME

Many programs in criminal justice and education have as one of their projected impacts the reduction of crime among the "treated" population. In order to estimate the benefits of such programs, it is first necessary to estimate the number of crimes of each type that will be avoided during each time period. Suppose N_{it} denotes the number of crimes of type i avoided in period t and C_i denotes the value of each crime type avoided. The benefits of avoided crime are the sum of the discounted value of N_{it} times C_i. Ideally, N_{it} is estimated using an experimental design as described in Chapter 11, which is expensive because one is interested in the number of crimes avoided over an extended period. Additionally, one must estimate C_i. Here it is quite common to use estimates from secondary sources.

We provide evidence from two sources that are summarized in Table 15.2: estimates of victim costs of violent crimes by Ted Miller, Mark Cohen, and Shelli Rossman and estimates of the monetary costs of a variety of different crimes by David Long, Charles Mallar, and Craig Thornton.[15]

TABLE 15.2 Plug-Ins for Cost of Crime (in 1999 U.S. dollars)

VICTIM COST OF CRIME		
1) Rape	1) $81,200 per rape ($63,700)	Based on Miller, Cohen, and Rossman (1993). Excludes criminal justice system costs. Pertains only to crimes that included some physical injury. Numbers in parentheses include attempted crimes and the cost of murder.
2) Robbery	2) $33,500 per robbery ($26,200)	
3) Assault	3) $30,000 per assault ($19,800)	
4) Arson	4) $66,700 per arson ($33,200)	
5) Murder	5) $3,207,100 per murder	
MONETARY COST OF CRIME		
1) Robbery	1) $35,000 per robbery	Based on Long, Mallar, and Thornton (1981). Relatively old study but good methodology, although excludes productivity losses and reduction in quality of life.
2) Burglary	2) $16,200 per burglary	
3) Larceny	3) $7,200 per larceny	
4) Drugs	4) $7,200 per drug crime	
5) Assault	5) $7,500 per assault	
6) Murder	6) $68,100 per murder	

The Miller and Colleagues' Estimate of the Cost of Violent Crime

Ted Miller and his colleagues provide two sets of estimates of the cost of violent crimes. The first set in Table 15.2, pertains to actually *completed crimes* of rape, robbery, assault, and arson that result in injury but do not involve murder. Crimes that do involve loss of life (murder) are a separate category. These numbers are essentially victim costs per crime. The second set, which is in parentheses, includes *attempted crimes*, again for each crime category, but also allocates murders to each category (primarily to assaults). These numbers are also victim costs per crime.

Miller et al. focus on the injury costs that result from these crimes. Specifically, their estimates incorporate the following three components: (1) the direct costs of crime-related injuries such as medical care and emergency response services, (2) costs resulting from forgone productivity (estimated as forgone earnings, forgone fringe benefits, and the value of forgone housework), and (3) costs resulting from reductions in the quality of life (mental health problems, pain and suffering, etc.). Their estimates do not include property damage, legal costs, and employer costs. Focusing on injuries captures most of the social cost associated with rape, robbery, assault, and murder. However, it is unlikely to provide a realistic estimate of the social cost of arson because much of the cost of this crime is property damage (many arsons involve no physical injury).

Long, Mallar, and Thornton's Estimates of the Monetary Cost of Crime

David Long, Charles Mallar, and Craig Thornton estimated shadow prices for a wide variety of crimes, including murder, assault, robbery, burglary, larceny, motor vehicle theft, and drug violations. They estimated three major components of crime cost: criminal justice system costs, the costs of personal injury and property damage, and losses associated with stolen property. Criminal justice system cost estimates were based on the probability and cost of each arrested person passing through the various stages of the criminal justice system: police custody, arraignment, detention, trial, and incarceration. Personal injury medical costs and property damage costs were estimated from data collected in the National Crime Panel Survey. Specifically, the cost per victimization was multiplied by the ratio of victimizations to arrests to estimate a "per capita arrest cost." The value of stolen property was estimated as follows. The researchers found that thieves were only able to realize 35 percent of the value of stolen goods. The researchers, therefore, treated 35 percent of the value of stolen goods as a transfer (from property owners to thieves) and multiplied the dollar value of stolen property by 0.65 (1–0.35) to estimate the social cost of stolen property. One could certainly argue, however, that it is inappropriate to give thieves standing. Long, Mallar, and Thornton do not include pain and suffering, productivity losses, or victims' willingness-to-pay to avoid crime.

As can be seen in Table 15.2, the estimated cost of murder varies dramatically depending on methodology and included costs. Using the Long-Mallar-Thornton approach leads to a much lower estimate of the per victim cost of murder than that of Miller. The Long-Mallar-Thornton approach illustrates the weakness of including only monetary costs. Ironically, murder may have quite low monetary costs: Perpetrators often plead guilty, thereby reducing criminal justice costs, and the medical costs of murder are low compared to other crimes that can often result in long medical treatments.

Because the estimates of the cost of crime cover different crimes, we summarize both studies in Table 15.2. The only cases in which there is more than one estimate for the same crime are robbery and murder. The two estimates for robbery are extremely close in same-year dollars.

THE VALUE OF TIME

Time is a valuable commodity; as the saying goes, "time is money." Time spent traveling, which individuals would be willing to pay to avoid, is a cost. Change in travel time is an important component of many CBAs, most obviously those concerned with transportation. Though rarely a dominating cost or benefit, change in waiting time can nonetheless be important in many nontransportation projects. For example, queuing time is an important cost component of policies that ration goods such as gasoline or access to services such as motor vehicle registration, medical care, or social services.

Almost all of the empirical literature on the value of time has been concerned with estimating the value of travel time. This is normally referred to as the *value of travel time savings* (*VTTS*), reflecting the fact that many transportation projects save time. We use this terminology, even though in other CBAs time may be expended, not saved. Also keep in mind that travel time savings may only provide a rough guide to the value of other time savings; for example, people usually experience considerably greater disutility from waiting time than from "pure" travel time.[16]

The large body of empirical literature on *VTTS* has been reviewed by several authors, mostly on a country-specific or regional basis. Typically, these have been commissioned by the relevant government and have led to the adoption of a standard *VTTS* for a country. For example, there have been reviews of the *VTTS* evidence in the United Kingdom, Canada, New Zealand, the Netherlands, the United States, and for developing countries.[17] In most cases, *VTTS* is expressed as a proportion of the before-tax or after-tax wage rate, as we discuss later. This allows analysts to readily estimate travel time costs using local wage rates. This is the approach we adopt in Table 15.3.

We primarily rely here on a review of the literature by William G. Waters II.[18] Waters reviewed the estimates of VTTS from 56 empirical studies conducted between 1974 and 1990. These studies comprise both revealed preference approaches and contingent valuation studies. Revealed preference approaches include a wide range of situations: route choice decisions in which there are different costs (e.g., toll roads versus nontoll roads); mode choice decisions (bus or car travel versus faster, but more costly, airline travel); speed choice decisions (in which faster speeds involve higher operating costs); and location choice decisions (hedonic methods that isolate the

TABLE 15.3 Plug-Ins for Value of Travel Time Saved

1) Nonwork travel time (commuting)	1) 40% to 50% of the after-tax wage rate per hour saved	Based on Waters (1996). High variance among studies. Must adjust to apply to other uses of time.
2) Work travel time	2) 100% of the before-tax wage rate (plus benefits) per hour saved	

impact of commuting time on land values). Survey methods are increasingly being used to estimate *VTTS* because they allow researchers to gather data of direct relevance to determining willingness-to-pay.

As is the normal procedure in the *VTTS* literature, Waters presents the results as a percentage of the after-tax (hourly) wage rate rather than as a dollar figure. He found as much as a tenfold variation in estimates from his literature review. As with other estimates described in this chapter, the studies cover a wide range of circumstances. Waters partitions these studies in a number of ways. He aggregates the 32 studies that focus on commuting trips and (after eliminating some outliers) calculates the mean value at 48 percent of the after-tax wage rate with a median of 40 percent. When this is reduced to the 15 North American automobile commuting studies, Waters calculates a mean of 59 percent (54 percent with the elimination of outliers) and a median of 42 percent. The 17 non–North American auto commuting studies generate a mean of 38 percent. Waters concludes that a shadow price between 40 to 50 percent of the after-tax wage rate is appropriate for auto commuting.

This conclusion is broadly consistent with that of Herbert Mohring and his colleagues regarding all intracity transit travel time: "[W]age earners with annual incomes greater than about US$30,000 value an hour of time in intracity transit at about half their equivalent hourly wage rates."[19] Governments have usually mandated the use of rates of between 40 percent and 60 percent of the hourly wage rate in CBA. The U.S. Federal Highway Administration currently uses 60 percent as the *VTTS* for highway projects, whereas Transport Canada recommends 50 percent for nonwork time savings.[20] Based on Waters and Mohring, we suggest valuing commuters' time saved at 40 percent to 50 percent of the after-tax wage (item 1 in Table 15.3), although government agencies sometimes prescribe a higher ratio.

It is usually useful to separate travel time savings into work time, commuting time, and leisure time. *Work time is usually valued at the before-tax wage rate plus benefits, whereas leisure time is valued somewhat less than commuting time.* Again, Waters points out that valuations vary widely: The ratio of *VTTS* for work and nonwork ranges from 1:1 to over 5:1. In fact, travel for sightseeing purposes may involve no opportunity cost of time, or even provide net travel benefits, at least up to some level of travel.[21]

THE VALUE OF RECREATIONAL BENEFITS

Over the last 20 years there have been a vast number of studies that estimate the value of various kinds of recreation. These studies generally rely on the travel cost or the contingent valuation method. Recreational facilities almost always provide both use benefits and nonuse benefits. Within the category of use benefits, we include rivalrous consumption (such as hunting), direct nonrivalrous consumption (such as hiking), and indirect nonrivalrous consumption (such as watching a movie about hiking in the wilderness). Within the category of nonuse benefits, which are discussed in more detail in Chapter 9, we include pure existence value (valuing the "natural order") and altruistic existence value (such as valuing other people's use or nonuse value of wilderness).

A review of 93 recreational value studies was conducted by Cindy Sorg and John Loomis in 1984.[22] In 1992, Richard Walsh, Donn Johnson, and John McKean updated and extended this earlier study.[23] In total, Walsh and his colleagues summarized the values for 287 studies that were performed between 1968 and 1988, including the 93 earlier studies. Unfortunately, there has been no comprehensive review of studies since 1988, although there are a large number of more recent individual estimates based on more sophisticated estimation techniques. Sorg and Loomis reported all values in 1982 dollars per "activity-day." They excluded studies for which it was not possible to calculate such a value. They made several adjustments, which were approved by an expert panel, to facilitate comparisons. The major adjustments were the conversion of "value per trip" to value per activity-day; the addition of time travel costs to other travel costs for studies that had not included this element (a 30 percent upward adjustment); an adjustment for the fact that differences in travel costs alter the probability of participation—essentially the demand for specific recreational activities is more inelastic than actually estimated (the downward adjustment in predicted use ranged from zero for highly specialized activities to 30 percent for nonspecialized activities); an adjustment to include the value to out-of-state visitors, when this value had not been included and when it was deemed likely to be important as, for example, in the case of big game hunting (a 15 percent upward adjustment); and an adjustment to contingent valuation studies that had not excluded protest bids (a 15 percent upward adjustment).

In Table 15.4 we report the mean estimate for each recreational activity as estimated by Walsh and his colleagues (items 1 through 16), updated to 1999 dollars. Two notes of caution are necessary given the large number of studies reviewed: Some part of the differences between valuations of different recreational activities is due to differences in estimation methodology and some part is due to quality differences across sites. Hiking and fishing, for example, are likely to be more valuable if they take place at more beautiful sites. It is almost impossible in practice to control for such differences.

TABLE 15.4 Plug-Ins for Value of Recreational Activities (in 1999 U.S. dollars)

1) Big game hunting	1) $66 per recreational day	Based on Walsh, Johnson, and McKean (1992).
2) Small game hunting	2) $45 per recreational day	
3) Water fowl hunting	3) $52 per recreational day	
4) Cold water fishing	4) $45 per recreational day	
5) Warm water fishing	5) $351 per recreational day	
6) Salt water fishing	6) $107 per recreational day	
7) Motorized boating	7) $46 per recreational day	
8) Nonmotorized boating	8) $72 per recreational day	
9) Swimming	9) $34 per recreational day	
10) Winter sports (skiing)	10) $42 per recreational day	
11) Hiking	11) $43 per recreational day	
12) Camping	12) $28 per recreational day	
13) Sightseeing and off-road driving	13) $29 per recreational day	
14) Wilderness	14) $36 per recreational day	
15) Picnicking	15) $26 per recreational day	
16) Total	16) $49 per recreational day	

EXISTENCE VALUE OF SPECIES

Literature surveys of existence value estimates are not yet available. Most studies provide estimates for specific activities or species, such as preservation of the bald eagle, the striped shiner, or the Californian condor.[24] Thomas Stevens, Jaime Echeverria, Ronald Glass, Tim Hager, and Thomas More provide relatively recent estimates of the average willingness-to-pay per person per year for four wildlife species reintroduced into New England.[25] These estimates are summarized in 1999 dollars in Table 15.5, along with other environmental values that are discussed later. The coyote is especially interesting because it has positive existence value to some persons (item 4, coyote preservation) and negative value to others (item 5, coyote control). Although we present these estimates of existence value, it is important to emphasize that both the concept of existence value and the methods used to estimate existence value (contingent valuation) have been seriously questioned.[26] On the other hand, there is no alternative.

TABLE 15.5 Plug-Ins for Value of Environmental Impacts (in 1999 U.S. dollars)

EXISTENCE VALUE OF SPECIES		
1) Bald eagle	1) $26 per person per year	Based on Stevens, Echeverria, Glass, Hager, and More (1991).
2) Wild turkey	2) $16 per person per year	
3) Salmon	3) $10 per person per year	
4) Coyote preservation	4) $7 per person per year	
5) Coyote control	5) $6 per person per year	
WATER QUALITY IMPROVEMENTS		
1) From unusable to boatable	1) $8 to $56 per year per household	Based on Luken, Johnson, and Kibler (1992).
2) From boatable to rough fishing	2) $12 to $48 per year per household	
3) From rough fishing to game fishing	3) $16 to $40 per year per household	
4) From game fishing to superior game fishing	4) $19 to $33 per year per household	
5) From unusable to superior game fishing	5) $40 to $144 per year per household	
COST OF NOISE		
1) Residential properties	1) 0.65% reduction in value per NEF	Based on Uyeno, Hamilton, and Biggs (1993). Consistent with previous studies.
2) Condominiums	2) 0.90% reduction in value per NEF	
3) Vacant land	3) 1.66% reduction in value per NEF	

TABLE 15.5 *(cont.)*

COST OF AIR POLLUTION		
1) PM10	1) \$25 to \$70 (\$40) per person per year per microgram per m^3	Based on Krupnick's (1995) Monte Carlo simulations. Numbers in parentheses are central estimates directly computed from coefficient estimates.
2) Lead	2) \$5.3 to \$16.5 (\$9.8) per person per year per .01 micrograms per m^3	
3) SO_2	3) \$1.3 to \$23.4 (\$10.7) per person per year per microgram per m^3	
4) Ozone	4) \$4.0 to \$11.0 (\$9.4) per person per year per .01 parts per million	
COST OF AIR POLLUTION		
1) VOCs	1) \$3,500 per ton per year	Based on Small and Kazimi (1995). Estimates reflect only health care costs of pollutants emitted by motor vehicles. These numbers are upper bounds for urban areas.
2) NO_x	2) \$12,700 per ton per year	
3) SO_x	3) \$130,500 per ton per year	
4) PM10	4) \$121,100 per ton per year	

BENEFITS OF WATER QUALITY IMPROVEMENTS

A variety of methods has been used to estimate the benefits of improvements in water quality for recreational, drinking, or for other purposes, including contingent valuation surveys, the market analogy method, defensive expenditures, and the travel cost method.[27] Table 15.5 summarizes shadow prices (annual household willingness-to-pay) for water quality improvements made by Ralph Luken, F. Reed Johnson, and Virginia Kibler who drew on previous studies of the Monongahela River.[28] These estimates are based on local recreation use and, therefore, should be limited to the relevant recreational market. Luken-Johnson-Kibler argue for 30 miles as an upper bound in defining the relevant markets for such recreational sites. They also recommend using visitation rates for households within this distance that range from 50 percent for sites with few substitutes to 10 percent for sites with numerous substitutes.

EXHIBIT 15.1

Ralph Luken wished to estimate the costs and benefits of (technology-based) water pollution standards introduced by the Clean Water Act of 1972. However, there were no existing estimates of *WTP* for improvements in the water quality of the rivers in question. Therefore, he utilized *WTP* estimates from existing studies as a basis for his estimates of the value of improvements in water quality.

He initially considered eight existing studies that might provide plug-in values. Five of the existing studies used the contingent valuation method, two studies used the travel cost method, and the eighth study was a user participation study. Luken eliminated five of the studies because their focus was not similar to the sites he was considering. These five studies dealt with water systems, such as those on a large western lake and a western river basin. His sites, in contrast, were generally eastern rivers with local recreation usage. Therefore, he focused on three studies: one on the Charles River in Boston and two on the Monongahela River in Pennsylvania. The Monongahela studies estimated benefits for three levels of improvement in water quality (from boating to fishing, from fishing to swimming, and from boating to swimming), whereas the Charles River study only examined improvements in water quality from boating to swimming (i.e., the biggest "jump" in quality). The summarized values as annual *WTP* per household (1984 dollars) are as follows:

	Water Quality Change		
River	***Boat–Fish***	***Fish–Swim***	***Boat–Swim***
Monongahela (contingent valuation)	$25–40	$14–23	$40–64
Monongahela (travel cost)	$8	$10	$18
Charles (contingent valuation)	—	—	$74

Unfortunately, these benefit categories did not directly map into the benefit categories Luken was using, which covered five quality improvement levels: *U* = Unusable, *B* = Boatable, *R* = Rough fishing, *G* = Game fishing, and *G** = Superior game fishing. Luken assumed that the travel cost method estimates provided lower-bound estimates (because they include only use valuations) and the contingent valuation estimates provided upper-bound estimates (as they include nonuse as well as use valuations). As shown next, he also included intrause estimates to reflect smaller benefit improvements. His plug-in values for water quality benefits (willingness-to-pay per household per year in 1984 dollars) follow:

Initial Water Quality	***Final Water Quality***	***Lower Bound***	***Upper Bound***
U	U	$1–3	$9–18
U	B	$5	$35
U	R	$15	$50
U	G	$20	$80
U	G*	$25	$90
B	B	$2–4	$8–15
B	R	$8	$30
B	G	$15	$50
B	G*	$20	$60
R	R	$3–5	$6–13
R	G	$10	$25
R	G*	$15	$35
G	G	$3–6	$5–10
G	G*	$12	$20

Although the purpose of this exhibit is to illustrate the use of secondary sources, it is interesting to note that in using these values, Luken generally found that costs exceed benefits.

Sources: Frederick W. Gramlick, "The Demand for Clear Water: The Case of the Charles River," *National Tax Journal*, 30, no. 2 (1977), 183–195; Ralph A. Luken, *Efficiency in Environmental Regulation* (Boston: Kluwer Academic Publishers, 1990), pp. 45–50, pp. 88–90; V. Kerry Smith and William H. Desvousges, *Measuring Water Quality Benefits* (Boston: Kluwer-Nijhoff Publishing, 1986); V. Kerry Smith, William H. Desvousges, and Ann Fisher, "A Comparison of Direct and Indirect Methods for Estimating Environmental Benefits," Working Paper No. 83-W32, Vanderbilt University, Nashville, TN, 1984.

THE COST OF NOISE

Cost of noise estimates are mostly relevant in the evaluation of transportation projects. The dominant method for estimating the cost of noise is the hedonic pricing method using differences in property values, usually those of private residences. Noise is measured in units of *NEF*s (ambient noise is in the 15–25 *NEF* range, "some" to "much" annoyance occurs in the 25–40 *NEF* range, and "considerable" annoyance occurs above 40 *NEF*s).

Since a survey by Jon Nelson in 1980, there have been relatively few studies of the cost of noise.[29] We report more recent estimates from a study by Dean Uyeno, Stan Hamilton, and Andrew Biggs.[30] Uyeno-Hamilton-Biggs specify a semi-log hedonic price function in which the price of a house (in logarithms) is a linear function of noise (in *NEF*s) and other house quality characteristics. The estimated slope of this function with respect to noise (multiplied by −100) measures the "noise depreciation sensitivity index" (*NDSI*).[31] The *NDSI* can be interpreted as an estimate of the percentage reduction in the value of a house resulting from a one-unit increase in the noise level (measured in *NEF*s). Uyeno-Hamilton-Biggs estimate that the *NDSI* was 0.65 percent for detached houses with *NEF*s of 25 or higher. In other words, if the noise level increases by 1 *NEF*, then the price of an affected house decreases in value by 0.65 percent on average. Thus, houses adjacent to an airport with *NEF*s of 40 are priced 9.75 percent lower than houses further from the airport with *NEF*s of 25. This *NDSI* 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) . . .".[32] Because of this consensus, Table 15.5 provides only the Uyeno-Hamilton-Biggs estimate.

THE COST OF AIR POLLUTION

Air pollution results in both health costs and nonhealth costs. The health cost of air pollution includes the costs of premature death and the costs of morbidity.[33] Nonhealth costs that result from air pollution include deforestation, retarded plant growth and reduced agricultural output, coastal erosion, damage to materials such as rubber, property losses, and losses of views. Air pollutants are emitted from many sources, especially motor vehicles, industrial plants, and power plants.[34] Important pollutants are volatile organic compounds (VOCs), nitrogen oxides (NO_x), sulfur oxides (SO_x), carbon oxides (CO_x), chlorofluorocarbons (CFCs), and particulate matter of less than 10 microns in diameter (PM10). VOCs combine with NO_x to produce ozone, which is a primary contributor to morbidity (illness). Through chemical reactions SO_x, VOCs, and NO_x produce PM10s, which cause both premature death and morbidity, especially respiratory diseases. The solution of SO_x and NO_x in cloud and rain droplets causes acid rain, which is known to damage pine and spruce forests, and is thought to damage tobacco, wheat, and soya crops. Acid rain also damages buildings, increases the acidification of lakes, and affects fish populations.[35] CFCs cause significant depletion to the ozone layer, which increases exposure to ultraviolet radiation and can damage crops and cause skin cancer as well as cataracts. The accumulation of carbon dioxide and other gases (including NO_x and CFCs) causes global warming.[36]

One approach to measuring the costs of damage associated with air pollution is to use dose response functions that relate unit increases in each pollutant to various health effects. They can, for example, be related to increases in the probability of premature death and increases in different types of respiratory problems. These effects are then weighted by dollar valuations, which are usually based on *WTP* estimates. A very different and frequently used approach involves the estimation of hedonic property value models.

We review three sets of estimates. Alan Krupnick provides recent estimates of the annual health costs per person attributable to PM10, sulfur dioxide, lead, and ozone, based on dose response functions.[37] In 1995, V. Kerry Smith and Ju-Chin Huang conducted a meta-analysis of 86 hedonic property value estimates based on 37 different studies conducted between 1967 and 1988.[38] Kenneth Small and Camilla Kazimi recently reported estimates of the annual costs of adding one ton of various pollutants for the Los Angeles area.[39]

The Krupnick Monte Carlo Estimates

Krupnick's estimates include both morbidity and mortality costs, except for SO_2, which includes only mortality costs. With the exception of ozone, mortality costs dominate. The per person per year ranges reported in Table 15.5 (items 1 through 4) may be viewed as 95 percent confidence intervals derived from Monte Carlo simulations, whereas the numbers in parentheses are point estimates directly computed from estimated coefficients.

The Smith and Huang Meta-Analysis

Each of the studies analyzed by Smith and Huang attempted to measure the impact of a one-unit change in total suspended particulates on the asset value of a typical house in one or more cities. The mean estimate is $183 per house per microgram per cubic meter (in 1999 dollars). However, Smith and Huang note that this value is substantially inflated due to a few outliers; the median value of the 86 estimates is only $37 per house per microgram per cubic meter. The variation in the estimates partially reflects the fact that they are for different cities, are estimated with different data, pertain to different time periods, and are based on different models and estimation techniques. Smith-Huang suggest that although the hedonic estimates partially reflect perceived health effects from pollution, they are probably more strongly influenced by "aesthetics, materials and soiling effects."[40] Indeed, they provide evidence that suggests that the dose response function approach results in much larger estimates of costs resulting from air pollution than does the hedonic property value approach. The Smith-Huang estimate is not presented in Table 15.5 as its hedonic value cannot be normally used directly as a plug-in.

The Small and Kazimi Estimates of the Health Care Costs of Pollutants from Vehicles

Unlike estimates of the value of a life or the cost of a crime, estimates of the cost of pollution on a per particulate unit basis are difficult to grasp intuitively and, for some purposes, may not provide a very convenient shadow price. Thus, Table 15.5 also presents estimates of the annual cost of adding one ton of various types of pollutants to the air.

The Small and Kazimi estimates are limited to health costs resulting from pollutants emitted by motor vehicles, costs that perhaps constitute the bulk of the costs engendered by air pollution in many urban areas. Their estimates imply that adding a ton of either SO_x or PM10 to the air is much more costly than adding a ton of either VOCs or NO_x. Moreover, consistent with Krupnick's estimates, Small and Kazimi's findings indicate that most of the costs of air pollution result from premature death rather than from illness. Because the locus of their study, the Los Angeles basin, is especially conducive to chemical reactions that produce pollutants and the area's mountain barriers are notorious for trapping pollutants, comparable values for other cities in the United States would be much smaller.

Like Krupnick's estimates, Small and Kazimi's estimates are based on dose response functions, dollar valuations of the various morbidity effects of pollution, and an estimate of the value of life. Their baseline cost estimates assume a value of life of about $5.6 million (in 1999 U.S. dollars). Earlier we suggested that a value about two-thirds as high may be more appropriate.[41] Use of this smaller value would cause the mortality cost estimates to fall proportionately. Small and Kazimi's estimates also require a value for the amount of ambient PM10 concentration in the air in Los Angeles. They use 57.8 micrograms per cubic meter, which is based on annual readings for downtown Los Angeles. As already suggested, this value is likely to be much higher for Los Angeles than for most other urban areas. Use of a smaller value would also cause Small and Kazimi's baseline estimates to fall proportionately.

Small and Kazimi also estimate the pollution cost of driving a motor vehicle one mile. Their baseline estimate is about 3 cents per vehicle-mile for a typical automobile (or roughly 53 to 63 cents per gallon) and 56 cents per vehicle-mile for a heavy-duty diesel truck driven in Los Angeles. These costs were predicted to fall to 1.9 cents and 42 cents (in 1999 dollars), respectively, by the year 2000 as newer, less polluting vehicles replaced older vehicles. Comparable costs in other cities would be much smaller.

THE COST OF TAXATION: MARGINAL EXCESS TAX BURDEN

Government projects often involve expenditures that have to be financed through taxes. As discussed in Chapter 4, taxes typically result in a deadweight loss—the marginal excess tax burden (METB). This loss or "leakage" occurs whenever there is a behavioral response to a tax—for example, an excise tax on a good causes purchases to fall or a tax on earnings causes workers to reduce their work hours. The marginal social value of the lost consumption or lost work is the deadweight loss of the tax. Important manifestations of the deadweight loss include the inefficient substitution of leisure for work, of barter for legal trade, and the search for tax loopholes. METBs vary according to the type of tax. In general, METBs are greater when the taxed activity is more elastic. The METBs from income taxes are higher than the METBs from property taxes and sales taxes.

Quite a few studies provide estimates of METB for specific taxes and countries, usually by assuming "reasonable" values of key parameters and then simulating the efficiency costs. Table 15.6 provides a range of estimates from the United States for a number of important tax "types": all taxes, income taxes, sales taxes, and property taxes. The ranges are derived from Charles Ballard, John Shoven, and John Whalley and from

TABLE 15.6 Plug-Ins for Marginal Excess Tax Burden per Dollar of Revenue

1) All taxes	1) $0.33 to $0.46	Lower values generally drawn from Ballard, Shoven, and Whalley (1985); higher values from Jorgenson and Yun (1990).
2) Sales tax	2) $0.11 to $0.39	
3) Income tax	3) $0.31 to $0.56	
4) Property tax	4) $0.17	

Dale Jorgenson and Kun-Young Yun, with the former generally obtaining lower estimates than the latter.[42] Ballard-Shoven-Whalley estimate the METB for all taxes combined is 33 cents per dollar, assuming the uncompensated saving elasticity is 0.4 and the uncompensated labor supply elasticity is 0.15. Using similar assumptions, Jorgenson-Yun estimate the METB for all taxes is 46 cents per dollar.

W. Erwin Diewert and Denis Lawrence provide estimates of the METB for different sectors in New Zealand.[43] Their estimated METBs for 1991 were $0.14 for general consumption taxation and $0.18 for labor taxation, which are lower than the values obtained for the United States. Interestingly, they find that for automobiles the METB is positive, implying that taxing automobiles has a benefit. The intuition behind this result is that taxing automobiles reduces pollution and other negative externalities.

Which METB is relevant to CBA? With respect to federal projects in the United States, it is probably reasonable to view income taxes as the marginal tax source, suggesting that the appropriate METB would be about $0.40. With respect to local government projects, the marginal tax source is more reasonably viewed as the property tax, which has an METB of around $0.17.

TRANSFERRING AND ADJUSTING PLUG-IN VALUES

Most of the estimates discussed in this chapter are averages, based on many studies. For example, the per-day values of recreational activities are averages based on a survey of over 200 articles. Ideally, these values should be adjusted depending on the specifics of a particular application.[44] Here we briefly review four sets of relevant factors: (1) differences in socioeconomic and other personal characteristics of the population (e.g., income and age), (2) differences in physical and other characteristics of the jurisdiction (e.g., geographic characteristics), (3) differences in the characteristics of the project itself (e.g., project quality), and (4) temporal changes.

Income and Other Socioeconomic Factors

It is often important to make adjustments due to socioeconomic differences or preference differences among different populations. Perhaps the most important variable is income; higher-income people can and do place higher values on their lives and other goods. Thus, they value their travel time savings more than lower-income people[45] and people in wealthy districts value the effect of pollution on house prices proportionately more than those in poor districts.[46] Air travelers who, on average, have higher incomes place higher (implicit) value on their lives.[47]

Thus, both evidence and economic theory suggest that shadow price estimates should be adjusted upward for projects that affect people with higher than average incomes and should be adjusted downward for projects that affect people with lower than average incomes. On the other hand, arguments in favor of the use of distributional weights in cost-benefit analysis, as described in Chapter 18, suggest that the costs and benefits of people in lower income groups should receive greater weight than those of higher income groups. In view of these conflicting considerations, it is probably reasonable to use population values.

Waters has examined how estimates vary with income, time (year of study), country, and trip purpose (interurban versus commuting or "other").[48] He finds that *VTTS* increases with income but less than proportionately:

$$VTTS_Y = \left(\frac{Y}{\overline{Y}}\right)^{0.5} \overline{VTTS} \qquad \textbf{(15.1)}$$

where $VTTS_Y$ is the *VTTS* of a traveler with income Y, $\overline{Y}$ is the average income level, and $\overline{VTTS}$ is the average *VTTS*. He suggests that a convenient rule of thumb for the relationship is a square root rule. Using such a rule, the *VTTS* rises more slowly than does income. For example, if income goes up fourfold from the average, the *VTTS* only doubles.

The relationship between *VTTS* and other variables appears to be weak. Waters found that *VTTS* increases over time (drifting upward at one percentage point per year) and that interurban travel has a slightly higher value than trips for other purposes.

For the most part, the estimates discussed here are based on U.S. research (and, indeed, sometimes on specific regions). Differences in incomes and tastes bring into question the appropriateness of using these estimates to analyze projects in other countries. Although there are no established rules of thumb to provide guidance, analysts should consider modifying them to take account of differences in other countries that affect *WTP*. For example, it would be reasonable to assume that the cost of injuries or crime is lower in Spain than in the United States, given differences in incomes and, possibly, preferences.

Preferences may also differ from one region to another or from one occupational group to another. People who live near airports may object less than others to aircraft noise, people who live in polluted areas may not value changes in air quality as much as people who live in areas with better air quality, and people who work in dangerous jobs may have greater propensity for risk than the average worker. Such differences in preferences affect how much people are willing to pay for particular policy effects.

Physical Characteristics

The second set of factors that may affect the transferability of plug-in values is physical and other characteristics of a region. For example, the impact of air pollution varies widely geographically, depending on population density, climate, and topography. More people are affected in more densely populated areas. *Ceteris paribus*, the greater precipitation in Vancouver means that the morbidity costs of NO_x or particulate matter are lower there than in Los Angeles.

The current level of a good in a region may affect the value of changes in the amount of that good. In general, holding all other factors constant, people are willing to pay more (less) for safety-improving projects as the level of safety decreases (increases). Consequently, the value of life used in a project that saves lives in a "high-risk" area should be higher than the value of life used in a project that saves lives in a "low-risk" area, holding all other relevant factors constant.

Project Differences

The third set of factors pertains to the similarity between the policy under evaluation and the projects in the studies used to derive the plug-in values. For example, the value of water quality improvement obtained from studies involving small improvements in quality levels may not apply to a proposed policy that would involve a large change in the level of water quality. The magnitude of the error in the generalization depends on the degree of nonlinearity in the relationship between water quality improvements and willingness-to-pay. Additionally, there may be important differences in the price and availability of substitutes, which, if not accounted for, can cause biases.[49] In sum, policies or projects under evaluation should ideally be similar to the projects in the studies used to derive the plug-in values in terms of the availability and quality of alternatives.

Temporal Changes

The final set of factors that should be considered involves those relating to the fact that valuations may change over time. Technological change, as well as temporal changes in population characteristics or jurisdictional characteristics, may affect the plug-in estimates. For example, increasing incomes and declining supply of accessible recreational areas might increase the value of such activities, whereas increasing congestion at the sites might decrease the value of such activities. Implicitly, by updating all of the original estimates using the composite CPI index, we assume no change in the relative shadow price of each activity since the original study was performed.

CONCLUSION

By making use of the plug-in values presented in this chapter, analysts can apply CBA to a wider range of policies than would be feasible if all shadow prices had to be estimated firsthand. When resources are available, analysts can make their own estimates and check them against those reported here.

Exercises for Chapter 15

1. A 40-mile stretch of rural road with limited access is used primarily by regional commuters and business travelers to move between two major interstate highways. The legal speed limit on the road is currently 55 miles per hour (mph) and the estimated average speed is 61 mph. Traffic engineers predict that if the speed limit were raised to 65 mph and enforcement levels were kept constant, the average speed would rise to 70 mph.

   Currently, an average of 5,880 vehicles per day use the stretch of road. Approximately half are commuters and half are business travelers. Traffic engineers do not expect that a higher speed limit will attract more vehicles. Vehicles using the road carry, on average, 1.6 people. Traffic engineers predict that raising the speed limit on this stretch of road would result in an additional 52 vehicle crashes involving, on average, 0.1 fatalities annually. They also predict that operating costs would rise by an average of $0.002 per mile per vehicle.

The average hourly wage in the county in which the majority of users of the road work is $12.20/hour.

Estimate the annual net benefits of raising the speed limit on the road from 55 mph to 65 mph. In doing this, test the sensitivity of your estimate of annual net benefits to several alternative estimates of the value of time savings and the value of life that you have selected from the chapter.

2. Analysts estimate that the expansion of the capacity of the criminal courts in a city would require about 7,200 additional hours of juror time. The average wage rate in the county is $10/hour. A recent survey by the jury commissioner, however, found that the average wage for those who actually serve on juries under the present system, who are also currently employed, is only $6/hour. The survey also found that about one-third of those who actually serve on juries under the existing system do not hold jobs—for example, they are homemakers, retirees, or unemployed.
   a. What shadow price should the analysts use for an hour of jury time?
   b. About a quarter of jurors do not receive wages from their employers while on jury duty. How does this affect your choice of the shadow price?

Notes

1. This chapter draws upon Anthony E. Boardman, David H. Greenberg, Aidan R. Vining, and David L. Weimer, "Plug-In Shadow Price Estimates for Policy Analysis," *Annals of Regional Science*, 31, no. 3 (1997), 299–324.
2. For example, Tae Hoon Oum, W. G. Waters II, and Jong-Say Yong surveyed over 60 studies of own-price elasticities of transport demand, "Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates: An Interpretative Essay," *Journal of Transport Economics and Policy*, 26, no. 2 (1992), 139–154. A companion survey by Philip Goodwin reviews empirical estimates of public transit and auto usage, "A Review of New Demand Elasticities with Special Reference to Short and Long Run Effects of Price Changes," *Journal of Transport Economics and Policy,* 26, no. 2 (1992), 155–169.
3. For example, on gasoline demand, see Molly Espey, "Explaining the Variation in Elasticity Estimates of Gasoline Demand in the United States: A Meta-Analysis," *Energy Journal*, 17, no. 3 (1996), 49–60, and Molly Espey, "Gasoline Demand Revisited: An International Meta-Analysis of Elasticities," *Energy Economics*, 20, no. 3 (1998), 273–295.
4. For example, one recent study suggests that transportation and communications are substitutes. See E. A. Selvanathan and Saroja Selvanathan, "The Demand for Transport and Communication in the United Kingdom and Australia," *Transportation Research—B*, 28, no. 1 (1994), 1–9.
5. For our purpose, *value* and *cost* can be used interchangeably, but we stick with common nomenclature—that is, we refer to "the value of (a lost) life" and "the cost of injury."
6. Ted R. Miller, *Narrowing the Plausible Range Around the Value of Life* (Washington, DC: The Urban Institute, 1989); Ann Fisher, Lauraine G. Chestnut, and Daniel M. Violette, "The Value of Reducing Risks to Death: A Note on New Evidence," *Journal of Policy Analysis and Management*, 8, no. 1 (1989), 88–100; W. Kip Viscusi, "The Value of Risks to Life and Health," *Journal of Economic Literature*, 31, no. 4 (1993), 1912–1946.
7. This is analogous to the dichotomous-choice method discussed in Chapter 14. With the dichotomous-choice method, this problem is dealt with by offering different individuals different prices. This does not normally occur in markets.
8. Scott E. Atkinson and Robert Halverson, "The Valuation of Risks to Life: Evidence from the Market for Automobiles," *Review of Economics and Statistics*, 72, no. 1 (1990), 332–340.
9. Dorothy P. Rice, Ellen J. MacKenzie, and Associates, *Cost of Injury in the United States: A Report to Congress* (San Francisco, CA: Institute for Health and Aging, University of California and

Injury Prevention Center, The Johns Hopkins University, 1989).

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