Ann Reg Sci (1997) 31:299–324

The Annals of Regional Science

"Plug-in" shadow price estimates for policy analysis

Anthony E. Boardman[1], David H. Greenberg[2], Aidan R. Vining[3], David L. Weimer[4]

[1]Faculty of Commerce and Business Administration, 2053 Main Mall, University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z2
(Tel.: 604/822-8474, Fax: 604/822-8477, e-mail: Anthony.Boardman@commerce.ubc.ca)
[2]Department of Economics, 1000 Hilltop Circle, University of Maryland Baltimore County, Baltimore, MD 21228, USA
[3]Faculty of Business Administration, Simon Fraser University, Burnaby, British Columbia, Canada V7A 1S6
[4]Public Policy Analysis Program, University of Rochester, Rochester, NY 14627, USA (Tel.: 716/275-5217, Fax: 716/271-1616, e-mail: dewr@troi.cc.rochester.edu)

Received: 15 August 1996 / Accepted in revised form: 19 February 1997

Abstract. In assessing existing or proposed public policies, analysts often need shadow price estimates for one or two key items – for example, the value of a human life, the cost of various types of injuries, the cost of a robbery or the value of an hour of travel time saved. This paper provides estimates of the values of many, frequently encountered impacts. These estimates are intended to be "plugged-in" to analyses of policy alternatives. Although these estimates may not be sufficiently accurate for some policy decisions, they will be very helpful in many policy situations.

1. Introduction: the rationale for plug-ins

In order to assess existing or proposed public policies, analysts require credible measures of the social values of their impacts.[1] Where impacts occur in efficient markets, their social values can usually be readily and appropriately estimated from changes in market prices and quantities. For example, the expected social cost of materials and labor for transportation projects can usually be directly derived from local labor and materials markets. When there are market failures or there is no market at all, then analysts need a shadow price – for example, the value of a human life saved,

An earlier version of this paper was presented at the Western Regional Science Association Meetings, Napa Valley California, February 1996. We would like to thank participants at that session for helpful comments, especially Jack Knetsch and Dale Whittington. We would also like to thank Bill Waters and the referees.
Correspondence to: A.E. Boardman

[1] Throughout this article we use the term policy broadly to incorporate programs and regulations.

the cost of various types of injuries, the cost of a robbery or the value of an hour of travel time saved.[2]

Often, these shadow prices are key factors in determining whether a policy has positive or negative net benefits. For example, Boardman et al. (1994) found that the net present value (NPV) of a major highway project was highly sensitive to the value of a life saved and the value of time saved.

In order to obtain the value of a non-market impact, analysts might conduct their own valuation study. If so, there are many alternative approaches. Valuations may be derived from demonstration projects, they may be based on observed behavior (e.g. intermediate good method, hedonic pricing, travel cost method, defensive expenditures, etc.) or they may be imputed from surveys (Boardman et al. 1996, pp. 250–370). Deriving original estimates for non-market values requires conducting a "study within a study." Unfortunately, such an effort almost always requires more time, effort and financial resources than are budgeted for the entire policy analysis. Usually, therefore, this is not a practical approach.

Consequently, analysts must usually rely on expert judgment, ad hoc estimates or on secondary sources. Too often researchers do not provide the basis for their valuations (e.g., Forslund and Johansson 1995, p. 169). Sometimes, shadow price estimates for policy impacts do exist, but analysts have difficulty selecting the appropriate value. In other cases, reported shadow prices are not readily accessible to analysts because there are few keywords to access them or they are in unpublished government documents. Furthermore, when analysts do discover multiple sources, they will often find that the estimates differ considerably. It generally takes a comprehensive review to obtain a credible estimate.

Researchers have recently conducted meta-analyses of studies that value specific impacts, as we will discuss later. However, each of these studies concerns the value of only one impact. The purpose of this paper is to present in one place a comprehensive set of shadow prices for a range of impacts, thereby lowering the cost of conducting quantitative analyses and promoting greater use of cost-benefit and policy analysis. Section 2 briefly explains the selection criteria for the shadow price estimates – the plug-ins. Section 3 presents and discusses the plug-in estimates. Section 4 reviews issues concerned with tailoring or "transferring" these estimates to any given situation. Section 5 concludes the paper.

2. Selection of shadow prices for inclusion as plug-in values

Often the direct costs of a policy can be estimated by applying market prices to the quantities of real resources required for its implementation.

[2] By "shadow price estimate" we simply mean an estimate of what a typical person would be willing to pay either to avoid something undesirable (e.g., air pollution) or to obtain something desirable (e.g., arriving at one's destination more quickly when taking a trip) in circumstances in which these amounts cannot be directly observed as prices in undistorted markets.

For example, engineering experience allows analysts to predict with reasonable confidence the labor, materials and equipment required to build a highway, and these inputs can be valued at their prices in competitive markets. However, other costs, such as environmental degradation, and many benefits, such as reductions in fatalities, accidents, and traval time, cannot be reasonably estimated directly from market prices.

Basically, there are three broad policy arenas of interest to regional scientists and other policy analysts: transportation/infrastructure, natural resources/environment and human resources, as shown in Table 1. "Transportation/infrastructure" includes highway construction and improvement, utilities (e.g. dams) and special events (e.g. Expo, Olympics). "Natural resources/environment" includes mining, creation and upgrading of public parks, and wetlands preservation. "Human resources/scientific/social" includes a broad range of educational, training, technological, scientific, health and crime prevention programs. These policies tend to require a lower proportion of physical investments to human capital. While they may result in product outputs and process changes, they are more likely to have non-physical benefits.

For policies, programs or regulatory changes in each of these broad categories, Table 1 distinguishes between impacts and other desired parameters that can reasonably be estimated using market data and those that cannot.[3] Many important effects commonly require shadow prices for their valuation as social costs or benefits. The availability of plug-in values for these impacts can greatly expand the range of policies to which cost-benefit analysis can be reasonably applied by analysts seeking to contribute to discussions of alternative public policies.

Two shadow prices are particularly valuable because of their broad application across all of the policy areas: the marginal excess tax burden and the social discount rate. The marginal excess tax burden measures the size of deadweight losses associated with various methods of raising government revenue. It should be applied to all net incremental changes in government budget outlays funded by taxes. The literature provides estimates of the marginal excess burden which we present and discuss as plug-in values.

Determining the appropriate social discount rate, which measures how society values tradeoffs between benefits occurring in different time periods, poses a vexing problem for policy analysts. Its many alternative interpretations as well as its relationship to issues of risk, make its conceptual foundations complex and its selection controversial. Furthermore, this topic has been reviewed extensively elsewhere; see, for example, Lind et al. (1982), Lyon (1990), and Boardman and Greenberg (forthcoming). Consequently, we do not provide a plug-in value for the social discount rate.

Beyond the marginal excess tax burden and the social discount rate, we provide plug-in values for shadow prices with broad application. Fortu-

[3] Note that regional development variables such as local employment, land values and consumer spending are not included as impacts. As Townroe and Dabinett (1995) and many others have noted, these are usually distributional effects, rather than appropriate cost-benefit variables. Housing is also not included because it often has large distributional impacts and, where it does not, its value can be readily obtained from market data.

Table 1. Impacts (costs and benefits) and other parameters requiring valuation

	Transportation/ infrastructure	Natural resources/ environment	Human resources/ technological/social
Valuations can be based on market prices	Construction resources: materials land labor equipment	Extraction/development resources: equipment labor materials water	Program resources: staff facilities equipment Product outputs
	Operations resources: labor maintenance	Product outputs	Process changes
	Fuel and operating cost savings	Process changes	
	Product outputs		
	Increased tourism		
Valuations require shadow prices	*Lives saved* *Injuries avoided* *Accidents avoided* *Time saved*	*Air quality changes* *Water quality changes* *Species preserved* *Recreational improvements*	*Crimes avoided* *Lives saved* *Injuries avoided* Health improvements
	Air quality changes	*Marginal excess tax burden*	Productivity improvements
	Water quality changes	Social discount rate	*Marginal excess tax burden*
	Noise level changes *Recreational improvements* *Marginal excess tax burden* Social discount rate		social discount rate

Plug-in values relevant to italicized effects are provided in Table 2.

nately, researchers have naturally tended to focus their attention on shadow prices of general interest, especially those for life, time, and injury, which arise in a great variety of policy areas. We provide plug-in values for these shadow prices, as well as for some others: crimes avoided, air and water quality improvements, outdoor recreational services, and existence values of species. Looking across the policy areas listed in Table 1, aside from the social discount rate, shadow prices for health improvements and productivity improvements are the only categories of broad application for which there is not adequate research to support the reasonable provision of plug-in values.[4]

[4] Researchers and policy makers are generally unwilling to value many health impacts and, consequently, cost-effectiveness and cost-utility analysis are used much more frequently than cost-benefit analysis in health care. Productivity improvements are too dependent on the characteristics of particular programs to justify a credible point or interval estimate for use as a plug-in.

3. The plug-in values

The plug-in estimates are presented in Table 2. The units of each impact are consistent with the relevant literature dealing with estimation of that particular impact. Most plug-in values are expressed as discounted present values per person or per event in 1994 U.S. dollars using the consumer price index (CPI) deflator.[5] This conversion to a single base year facilitates comparability. The impacts vary considerably in terms of their time span. Recreational activities, for example, last only a day and are measured in dollars per day. The existence values of specific species and the cost of specific air pollutants are measured in terms of dollars per year. For these values no discounting is involved. Discounting is only relevant to the value of a life saved, some injuries and some crimes. Some studies discount future events using a 2.5% discount rate (Miller 1990), some use a 4% rate (Miller 1993), some use a 6% rate (Rice et al. 1989), while in other studies the discount rate is an estimated parameter.[6] The value of time saved and the cost of noise are reported as ratios or percentages and will be discussed later. The units of each impact are stated clearly.

The values in Table 2 are based on an extensive review of current research. Where there has been only one reliable study of the value of an impact, the estimates are based on that study. Where there have been many articles we provide a range, weighting the more reliable estimates more heavily. When many studies are involved the estimate can be considered as a weighted average of existing studies. For values of some impacts we draw on extensive literature reviews. Also, where available, we draw on meta-analyses of many existing studies.

We now discuss each of the estimates in Table 2, providing information concerning the sources from which it was obtained, its reliability, and how it was derived. We also review some of the kinds of policies for which these shadow prices are relevant. Of course, readers should consult the original sources for greater detail.

Some sections are more extensive than others. One reason is that some topics, such as the value of life, have been researched in much more depth than others, such as the value of water quality improvements. The length of each section also depends on whether or not there is a good survey article on that topic. For example, the section on the value of time can be short due to a recent comprehensive review. Finally, some topics require more attention because they are conceptually more complicated than others.

The value of life

Estimates of people’s willingness to pay to avoid mortality risks, the so-called value of life, are often important for evaluating health care programs, transportation projects, and safety and environmental regulations. Most recent estimates of the “statistical” value of life are based on the after-tax

[5] For a recent discussion of the bias in the CPI, see Moulton (1996).
[6] These estimates range from 1 to 14% (Viscusi 1993, p. 1922).

Table 2. Shadow prices for policy analysis (in 1994 US dollars)

Plug-in category (impact)	Shadow price value	Comments
Value of life	$ 2.25–$ 3.5 million per life saved	Based primarily on Miller (1989 b). See also Fisher, Chestnut and Violette (1989) and Viscusi (1993). Should adjust for risk level if known.
Monetary injury costs		
1) Eventually fatal	1) $ 436,900 per injured person	Based on Rice, MacKenzie and Associates (1989). Includes monetary costs only, not pain and suffering.
2) Hospitalized (non-fatal)	2) $ 47,000 per injured person	
3) Non-hospitalized (non-fatal)	3) $ 700 per injured person	
4) Average cost of an injury	4) $ 3,800 per injured person	
A) Motor vehicle injury	A) $ 12,500 per injured person	
B) Falls	B) $ 4,200 per injured person	
C) Firearm injuries	C) $ 74,100 per injured person	
D) Poisonings	D) $ 6,900 per injured person	
E) Fire injuries and burns	E) $ 3,600 per injured person	
F) Drownings and near drownings	F) $ 89,500 per injured person	
G) Other	G) $ 1,600 per injured person	
Cost of work-related injury		
1) Less serious	1) $ 28,000 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 work days.
2) More serious	2) $ 57,000 per injured person	
Social cost of motor vehicle crash injuries		
1) Spinal cord	1) $ 1,827,800 per victim (0.66)	Based on Miller (1993) which, in turn, draws on Miller's (1989 b) $ 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) $ 106,000 per victim (0.04)	
3) Lower extremity	3) $ 178,300 per victim (0.06)	
4) Upper extremity	4) $ 69,300 per victim (0.03)	
5) Trunk/abdomen	5) $ 52,800 per victim (0.02)	
6) Face, other head, or other neck	6) $ 20,400 per victim (0.01)	
7) Minor external	7) $ 4,900 per victim (0.002)	
A) Average for non-fatal crash	A) $ 50,000 per victim (0.02)	
b) Average for fatal crash	B) $ 2,987,900 per victim (1.08)	
Monetary cost of firearm injuries		
1) Eventually fatal	1) $ 514,000 per injured person	Based on Max and Rice (1993). Includes monetary costs only, not pain and suffering.
2) Hospitalized (non-fatal)	2) $ 45,700 per injured person	
3) Non-hospitalized (non-fatal)	3) $ 600 per injured person	

Table 2 (continued)

Victim cost of crime		
1) Rape	1) $ 72,200 per rape ($ 56 700)	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) $ 29,800 per robbery ($ 23,300)	
3) Assault	3) $ 26,700 per assault ($ 17,600)	
4) Arson	4) $ 59,300 per arson ($ 29,500)	
5) Murder	5) $ 2,852,900 per murder	
Cost of crime		
1) Robbery	1) $ 31,100 per robber	Based on Long, Mallary and Thornton (1981). Relatively old sudy, but good methodology, although excludes productivity losses and reduction in quality of life.
2) Burglary	2) $ 14,400 per burglary	
3) Larceny	3) $ 6,400 per larceny	
4) Drugs	4) $ 6,400 per drug crime	
5) Assault	5) $ 6,700 per assault	
6) Murder	6) $ 60,600 per murder	
Value of travel time saved		
1) Non-work travel time (commuting)	1) 40–50% of the after-tax wage rate per hour saved	Based on Waters (1993). High variance among studies. Must adjust to apply to other uses of time.
2) Work travel time	2) 100% of the after-tax wage rate per hour saved	
Value of recreational activities		
1) Big game hunting	1) $ 59 per recreational day	Based on Walsh, Johnson and McKean (1992).
2) Small game hunting	2) $ 40 per recreational day	
3) Water fowl hunting	3) $ 46 per recreational day	
4) Cold water fishing	4) $ 40 per recreational day	
5) Warm water fishing	5) $ 31 per recreational day	
6) Salt water fishing	6) $ 95 per recreational day	
7) Motorized boating	7) $ 41 per recreational day	
8) Nonmotorized boating	8) $ 64 per recreational day	
9) Swimming	9) $ 30 per recreational day	
10) Winter sports (skiing)	10) $ 37 per recreational day	
11) Hiking	11) $ 38 per recreational day	
12) Camping	12) $ 25 per recreational day	
13) Sightseeing and off-road driving	13) $ 26 per recreational day	
14) Wilderness	14) $ 32 per recreational day	
15) Picnicking	15) $ 23 per recreational day	
16) Total	16) $ 44 per recreational day	
Existence value of species		
1) Bald eagle	1) $ 23 per year	Based on Stevens, Echeverria, Glass, Hager and More (1991).
2) Wild turkey	2) $ 14 per year	
3) Salmon	3) $ 9 per year	
4) Coyote preservation	4) $ 6 per year	
5) Coyote "control"	5) $ 5 per year	
Benefits of water quality improvements		
1) Unusable to boatable	1) $ 7–$ 50 per year per household	Based on Luken, Johnson and Kibler (1992).
2) Boatable to rough fishing	2) $ 11–$ 43 per year per household	

Table 2 (continued)

3) Rough fishing to game fishing	3) $ 14–$ 36 per year per household	
4) Game fishing to superior game fishing	4) $ 17–$ 29 per year per household	
5) Unusable to superior game fishing	5) $ 36–$ 128 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	
Cost of air pollution		
1) PM10	1) $ 22–$ 62 ($ 36) per person per year per µg 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) $ 4.7–$ 14.7 ($ 8.7) pp/yr per 0.01 µg per m^3	
3) SO_2	3) $ 1.2–$ 20.8 ($ 9.5) pp/yr per µg per m^3	
4) Ozone	4) $ 3.6–$ 9.80 ($ 8.4) pp/yr per 0.01 parts per million	
Cost of air pollution		
1) VOCs	1) $ 3,100 per ton per year	Based on Small and Kazumi (1994). Estimates reflect only health care costs of pollutants emitted by motor vehicles. These numbers are upper bounds for urban areas.
2) NO_x	2) $ 11,300 per ton per year	
3) SO_x	3) $ 116,100 per ton per year	
4) PM10	4) $ 107,700 per ton per year	
Marginal excess tax burden		
1) All taxes	1) $ 0.33–$ 0.46	Lower values generally drawn from Ballard, Shoven and Whalley (1985 a, b); higher values from Jorgenson and Yun (1990).
2) Sales tax	2) $ 0.11–$ 0.39	
3) Income tax	3) $ 0.31–$ 0.56	
4) Property tax	4) $ 0.17	

wage premia demanded by workers in risky jobs in order to compensate them for the additional risk. Some studies examine consumers' willingness-to-pay to take, or to accept, certain risks in markets for commodities that embody risks, for example, for safety features such as auto air bags and home smoke detectors. A few studies are based on contingent valuation surveys. As economists generally prefer to use revealed preference estimates when they are available, we place more emphasis on these estimates.[7] In practice, however, the mean estimate of the value of life from the contingent valuation surveys does not differ much from the mean esti-

[7] Overviews of contingent valuation include Cummings, Brookshire and Schulze (1986), Mitchell and Carson (1989), Hanley (1989), and Bishop and Heberlein (1990). For critiques see Hausman (1993) and also the recent debate in the *Journal of Economic Perspectives*, Fall 1994.

mates using other methods (Miller 1990). The variance in the estimates using a particular method differ more than the variance in the mean differences among methods.

The "statistical" value of life estimate of $ 2.25 million to $ 3.5 million comes primarily from Miller's (1989b, 1990) review of 49 studies, after conversion to 1994 dollars using the CPI deflator. Miller dropped 20 of the 49 studies because of insufficient sample size, poorly designed surveys, or failure to include appropriate risk variables. Using a consistent real discount rate of 2.5% across all studies, the mean value-of-life estimate for the remaining 29 studies was $ 2.7 million in 1994 after-tax dollars, with a range of $ 1.4 to $ 5.9 million and a standard deviation of $ 0.69 million.[8] Miller argued that these value-of-life estimates are sufficiently consistent with one another that one can have some confidence in them. He also concluded that the consistency among the findings implies that individuals appear to value life similarly whether the risk is largely voluntary (for example, accepting a dangerous job) or involuntary (the risk of a nuclear accident) and whether the potential death is slow and painful or sudden and painless.

Two other recent surveys of value of life studies suggest a much greater range of estimates than does Miller's survey and imply that our upper bound of $ 3.5 million may be low. For example, after reviewing estimates from 21 studies, Fisher et al. (1989, p. 96) conclude that "[t]he most defensible empirical results indicate a range for the value-per-statistical-life" of $ 2.2 to $ 11.5 million in 1994 dollars. However, they go on to state that "[o]n balance, we place more confidence in the lower end of the range" (p. 98). By far the greatest range of value of life estimates – $ 0.08 million to $ 18 million in 1994 dollars – are exhibited by the 38 studies reviewed by Viscusi (1993). In Viscusi's view, "most of the reasonable estimates of the value of life are clustered in the $ [3.4]–$ [7.9] million range".[9]

The cost of injuries

Table 2 presents four sets of estimates for the cost of injuries. The first set (monetary injury costs) is from original research conducted by Rice et al. (1989) and gives the average cost per injured person for all injuries (item 4) and the average cost per injured person for a variety of types of injuries, differentiated by severity (items 1–3), and by cause of injury (items A–G). Much of the variation in the average cost of different types of injuries is attributable to differences in average severity. For example, firearm injuries engender higher costs than average because they are more severe.

[8] Miller (1990, p. 18) states: "... the value of a life equals the value of a life year times the discounted sum of the remaining life years. At a discount rate between 2 and 5%, each year of difference in mean age (and, roughly, in life expectancy) in the 37- to 40-year age range leads to a 1 to 2% difference in the value of life." Thus, the value of life estimates are not very sensitive to the discount rate.

[9] For consistency we substitute 1994 dollar figures for Viscusi's stated figures, which are in 1990 dollars.

The second set (cost of work-related injury) is from Viscusi's (1993) survey of 14 studies that relied on after-tax wage premia for risky jobs. While these estimates are especially appropriate for evaluating regulations and other policies that affect work place safety, they can also be used as order-of-magnitude estimates of costs associated with accidents resulting from other sources.

The third set (social cost of motor vehicle crash injuries) is from Miller's (1993) study of injury costs resulting from automobile crashes. These estimates measure the cost per victim, categorised according to the victim's most life-threatening injury. These estimates are especially useful for analyses of projects that improve roads and regulations, mandate automobile safety features or change speed limits.

The fourth set (monetary cost of firearm injuries) by Max and Rice (1993) estimates the lifetime cost of firearm injuries, differentiated according to severity.

The Rice-MacKenzie and the Max-Rice estimates are quite different in nature from those surveyed by Viscusi or produced by Miller. The Viscusi and Miller estimates are based on willingness-to-pay approaches. Consequently, in principle, they incorporate the full cost of injuries to those who are injured, including reductions in the quality of life (e.g., pain and suffering). The Rice-MacKenzie and Max-Rice estimates, in contrast, incorporate only certain direct financial costs of injuries: medical treatment, rehabilitation, transportation costs and forgone earnings (including an imputed value for household labor). They do not include property damage losses, court costs or, most importantly, the disutility from pain and suffering resulting from injuries. Thus, they are less inclusive than the estimates reported by Viscusi or Miller, which more closely reflect social cost.

As indicated in Table 2, Rice-MacKenzie estimated injury costs for three levels of severity: fatalities (including delayed fatalities that are directly attributable to the injury), injuries requiring hospitalization, and injuries not requiring hospitalization. Their estimate of the cost of fatalities is much smaller than the value of life estimates discussed in the previous section because they capture only medical costs and forgone earnings resulting from dying, thereby omitting any additional losses of utility that individuals are willing to pay to avoid. This lack of comprehensiveness can be critical in the analysis of certain types of policies. For example, as Miller has pointed out, if injury costs are not measured comprehensively and do not include all costs, then the benefits of safety-enhancing highway improvements will be understated relative to time-saving road improvements. Indeed, a large enough understatement can make it appear that it is better to be dead than to be stuck in traffic![10]

Viscusi's summary of the estimated costs of work-related injuries appeared in the survey article discussed earlier and is based on willingness-to-pay. Although the 14 studies cover a wide range of injury sevently and

[10] Ascribed by Miller (1993, p. 605) to Ezra Hauser.

circumstances, Viscusi concludes that “[m]ost of the estimates based on data for all injuries regardless of severity are clustered in the $ [28,300]–[56,700] range [in 1994 dollars]”, with those involving losses of work days at the high end of this range (p. 1935). Notice that the Rice-MacKenzie estimate for nonfatal injuries requiring hospitalization falls well within this range.

Miller’s (1993) estimates of injury costs resulting from automobile crashes incorporate medical and emergency services, lost wages and household production, work place disruption, insurance administration costs, the costs of legal proceedings, and costs incurred by the pain and suffering resulting from injury. As previously pointed out, like Viscusi’s estimates of the costs of work-related injuries, Miller’s estimates are closer to the social cost than the Rice-MacKenzie calculations of the financial costs associated with injuries. However, they also differ in important respects from Viscusi’s estimates. One reason for this is that automobile injuries generally differ in severity from work-related injuries.

A more fundamental reason why Viscusi’s and Miller’s estimates differ is that Viscusi focuses on the private individual perspective, while Miller attempts to estimate the cost of injuries to society as a whole. Viscusi’s estimates incorporate only costs to the injured individual, as measured by his or her willingness-to-pay to recuce the risk of non-fatal injury. In contrast Miller’s estimates incorporate costs to the rest of society, as well as costs to the injured individual. Because Miller focuses on the societal perspective, his estimates do not include the value of insurance settlements, as such settlements simply represent transfers to accident victims from other members of society.

Although Viscusi and Miller both incorporate reductions in the quality of life in their estimates of the cost of injuries, they use different techniques to do so. Viscusi’s estimates are based on the premia that worker’s require to accept employment in riskier jobs. These premia presumably reflect all the differences inherent between a less risky and a more risky job, including the different probabilities of suffering reductions in one’s quality of life due to work-related injuries. In contrast, Miller’s approach involves three steps. Fist, survey respondents rate each type of injury on a “functional capacity loss” scale that has values between zero (death) and one (perfect health). This scale incorporates several relevant dimensions of the injury: cognitive, mobility, sensory and cosmetic losses; pain; reductions is daily functioning; and losses in the ability to perform work. The resulting ratings are then used to compute the quality-adjusted life years (QALYs) for each injury. Finally, the QALYs are multiplied by the value of a life lost per year, where the latter is derived from Miller’s (1989b) estimate of the value of a life.

Using the same approach as Rice-MacKenzie, Max-Rice obtained estimates of the costs of firearm injuries per injured person. The average cost was $ 74,100, which replicates the Rice-MacKenzie estimate. Firearm injuries are more costly than most other types of injuries because they are more likely to result in death or hospitalization.

The cost of crime

Numerous programs, particularly in criminal justice but also in education and training, have reductions in crime as one of their goals. Measuring the benefits of such programs requires estimates of the (avoided) costs of crimes. Table 2 presents two separate sets of estimates. Miller et al. (1993) focus on violent crimes while Long et al. (1981) estimate the cost of a variety of crimes.

Miller-Cohen-Rossman provide two sets of estimates. The first set, which are not in parentheses in Table 2, pertains to completed crimes of rape, robbery, assault and arson that result in injury (but do not involve murder), with crimes that do involve loss of life (murder) as a separate category. These numbers are essentially victim costs per crime. The second set, which are 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-Cohen-Rossman 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), (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 as much of the cost of this crime is property damage (many arsons involve no physical injury).

The Long-Mallar-Thornton estimates of the cost of crime include the following three components: (1) property damage and medical costs resulting from crime-related injuries, (2) criminal justice system costs, and (3) losses associated with stolen property. These estimates omit costs attributable to productivity losses due to crime-related injuries, quality of life losses resulting from crime-related injuries, and the value of lives lost due to crime-related deaths. Given what they include and omit, it is impossible to clearly describe their crime costs as representing either the full social cost or the victim cost per crime.

Estimates of property damage and medical costs were derived from data collected in the National Crime Panel Survey. Criminal justice system costs, which were the largest of three cost components, were estimated by multiplying the probability that a person arrested for a particular crime would pass through particular stages of the criminal justice system – for instance, police custody, arraignment, detention, trial, and incarceration – by the costs associated with each stage. To estimate the value of losses associated with stolen property, the authors first determined that, in fencing stolen goods, thieves realized only 35% of the value of these goods. They treated this 35% as an in-kind income transfer to the thieves from their victims and, consequently, treated only the remaining 65% of the value of stolen goods as a net loss to society. Others might argue that thieves should not be given standing in valuing the social cost of crime (that is, any benefits of a crime to its perpetrators should be ignored) and, hence, 100% of the value of stolen goods should be counted as part of the costs of the crime. Doing so, however, would result in only modest increases in the estimates.

Although Miller-Cohen-Rossman omit incremental criminal justice costs, property damage costs and the value of stolen property, their cost estimates do include pain and suffering and are therefore more plausible estimates of social costs than those provided by Long-Mallar-Thornton. Given the omissions, however, the Miller-Cohen-Rossman estimates are probably lower bounds.

The value of time

As the saying goes, “time is money.” The value of time needs to be taken into account in evaluating government projects that affect the use of time. Examples include projects that affect travel time, such as road building, and projects that affect queuing time by rationing goods, such as gasoline and medical services, or by increasing or reducing staffing at government offices that serve the public, such as motor vehicle or security claims centers.

Most of the empirical literature concerned with valuing time has focused on estimating the “value of travel time savings” or “VTTS.” Although it is possible to apply estimates of VTTS to non-transportation projects, one should keep in mind that people typically experience considerably greater disutility from queuing than from travelling (Mohring et al. 1987). Thus, time saved by reducing queuing time should be valued more highly than the VTTS.

In the policy literature VTTS are expressed as a proportion of the after-tax wage rate. This is useful to practising policy analysts because it allows them to adapt to local market conditions.

The empirical literature on VTTS is quite extensive. Government bodies in several countries have recently commissioned surveys of this literature to help them adopt a value to use in evaluating transportation projects.[11] The VTTS’ estimates that appear in Table 2 were obtained from a review of 56 empirical studies by Waters (1996). These studies were conducted between 1974 and 1990 and were based primarily on revealed preference methods. Revealed preferences were observed in a diversity of contexts: route choice decisions where there were different costs (for example, toll roads versus non-toll roads); mode choice decisions (bus or car travel versus faster, but more costly, airline travel), speed choice decisions (where faster speeds in-

[11] Countries that have done this include the United States (Texas Transportation Institute 1990; Miller 1989 a), the United Kingdom (Sharp 1988), Canada (Lawson 1989), and New Zealand (Miller 1989 a). In addition, the World Bank has commissioned a survey of VTTS estimates for use by developing countries (Bates and Glaister 1990).

volved higher operating costs); and location choice decisions (hedonic pricing methods that attempt to isolate the impact of commuting time on land values or residential values). Not surprisingly, estimates from these studies varied widely.

Thirty-two of these studies provide estimates of how individuals value their commuting time. The mean VTTS for commuters is 51% of their hourly after-tax wage rate (48% if the highest and lowest estimates are omitted), while the median VTTS for commuters is 40% of their wage rate. Considering only the 15 commuting studies that pertained to North America, Waters obtained a mean of 59% of the after-tax wage rate (54% after the elimination of the highest and lowest estimates) and a median of 42%. Waters concludes that around 40 to 50% of the hourly after-tax wage is an appropriate shadow value for time spent commuting. This conclusion is broadly consistent with results from Mohring-Schroeter-Wiboonchutikula and Miller's (1989a) survey. However, the more recent studies suggest using a slightly higher percent of the after-tax wage rate.

This estimate of VTTS pertains to non-work travel time, primarily the value of commuting time in urban areas. Waters suggests that for inter-urban and rural travel, slightly higher values may be appropriate. For travel time that directly displaces work, it is usual to use the after-tax wage rate (before taxes plus benefits) as the shadow price. Road improvements that save time for commercial truck drivers, for example, would generally be valued at the drivers' after-tax wage rates, but including overheads and fringe benefits.

The value of recreational benefits

The value of recreation benefits is of obvious importance in deciding among competing uses of natural resources. There have been numerous studies of the value of different types of recreational activities. These studies have usually relied on either the travel cost method or on contingent valuation surveys. The travel cost method exploits the fact that while the admission price for a particular recreational activity is constant for everybody (often zero), the full price, including the opportunity cost of travel time, varies depending on where visitors reside. By sampling individuals from different residential areas (zones) it is possible to observe different total costs per visit and different visit rates. This information can be used to estimate the demand curve for the site.

Recreational facilities provide both use benefits and non-use benefits. Within the category of use benefits we include rivalrous consumption (such as hunting), direct non-rivalrous consumption (such as hiking), and indirect non-rivalrous consumption (such as watching a film about a wilderness area). Within the category of non-use benefits we include pure existence value (valuing the "natural order") and altruistic existence value (such as valuing other people's use or non-use value of wilderness). We first discuss use value, then non-use value.

Estimates of use benefits for a wide range of recreational activities appear in Table 2. These estimates are based on Walsh et al. (1992), who updated and extended an earlier survey by Sorg and Loomis (1984). Benefits are reported in terms of dollars per recreation day. The values are consumer surpluses, that is, they measure the average amount survey participants are willing to pay for a particular recreational activity, over and above their current expenditures on getting to the site, clothing, equipment, etc.

The Walsh-Johnson-McKean survey is based on 287 studies that were conducted between 1968 and 1988, 93 of which were in the Sorg-Loomis survey.[12] Both of these surveys provide ranges of the value of each recreation activity based on reviews of the empirical literature, as well as a mean estimate, which is given in Table 2. Although much of the variation among the estimates of the value of a particular activity is due to differences in estimation methodology, some of it is attributable to quality differences across sites – for example, hiking or fishing may be more pleasurable in one area than another.

For many recreational facilities non-use benefits may be larger than use benefits. In fact, non-use benefits may "drive" an analysis. For example, Willis (1990) used contingent valuation to estimate the value of three nature sites of special scientific interest in Great Britain. Direct use benefits of the sites (including option value) accounted for only about 20 to 25% of total willingness-to-pay. Only if non-use benefits were included did conservation of these areas appear to have positive net social benefits.

Literature surveys of existence value estimates do not appear to be available. Most studies provide estimates for specific activities or species, such as preservation of the bald eagle, the striped shiner or the Californian Condor (see, e.g., Boyle and Bishop 1987; Bishop 1978). Stevens et al. (1991) provide relatively recent estimates of the average willingness-to-pay per year for four wildlife species reintroduced into New England. These estimates are shown in Table 2.[13] The coyote is especially interesting because it has positive existence value to some (coyote preservation) and negative value to others (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 (see, e.g., Rosenthal and Nelson 1992; Hausman 1993). On the other hand, there is no alternative.

A variety of methods have been used to estimate the benefits of improvements in water quality for recreational, drinking or for other pur-

[12] Walsh-Johnson-Loomis draw on the following number of studies: big game hunting, 56; small game hunting, 10; migratory water fowl hunting, 17; cold water fishing, 39; warm water fishing, 23; salt water fishing, 17; motorized boating, 5; nonmotorized boating, 11; swimming, 11; winter sports (downhill skiing), 12; hiking, 6; camping, 18; sightseeing, 6; wilderness, 15; picnicking, 7; total, 287.

[13] These estimates were converted to 1994 U.S. dollars by assuming Stevens-Echeverria-Glass-Hager-More conducted their survey in 1989, which is not clear from their article.

poses.[14] Table 2 reports shadow prices (annual household willingness-to-pay) for water quality improvements made by Luken et al. (1992) who drew on studies of the Monongahela River by Smith and Desvousges (1986) and Smith et al. (1984). 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% for sites with few substitutes to 10% for sites with numerous substitutes.

The cost of noise pollution and air pollution

Estimates of the cost of noise are mostly relevant in the evaluation of transportation projects. The dominant method for estimating the cost of noise is hedonic pricing. This method estimates the cost of noise using differences in property values, usually those of private residences. Noise is measured in units of NEFs (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 NEFs).

There have been relatively few studies of the cost of noise since Nelson's (1980) survey. However, three recent studies are O'Byrne et al. (1985), Pennington et al. (1990), and Uyeno et al. (1993). Uyeno-Hamilton-Biggs specify a semilog hedonic price function where the price of a house (in logarithms) is a linear function of noise (in NEFs) 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).[15] The NDSI can be interpreted as an estimate of the percentage reduction in the value of a house resulting from an one-unit increase in the noise level (measured in NEFs). Uyeno-Hamilton-Biggs estimate that, for detached houses with NEFs of 25 or higher, the NDSI was 0.65%. In other words, if the noise level increases by 1 NEF, then the price of an affected house decreases in value by 0.65% on average. Thus, houses adjacent to an airport with NEFs of 40 are priced 9.75% lower than houses further from the airport with NEFs 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

[14] Some studies have measured the benefits of improvements in drinking water quality through contingent valuation surveys (Jordan and Elnagheeb 1993). Another method used to value improvements in drinking water is the market analogy method which, in this context, uses observations of expenditures to purchase bottled water (Adballa, Roach and Epp 1992). A third method uses defensive expenditures to avoid harmful impacts, such as expenditures incurred in boiling or hauling water or installation of household treatment systems (Abdalla, Roach and Epp 1992). Other studies have estimated the benefits of water quality improvements on river segments through travel cost methods or contingent valuation (Smith and Desvousges 1986; Desvousges, Smith and Fisher 1987).

[15] Specifically, $\text{NDSI} = -100\,(\partial \ln(\text{H}) / \partial\,\text{NEF})$. In contrast, the hedonic price of noise or marginal implicit price of noise is the slope of the function relating house prices (H) to noise level, i.e. $\partial\,\text{H} / \partial\,\text{NEF}$.

noise on property values) ..." (p. 14). Because of this consensus, Table 2 contains only the Uyeno-Hamilton-Biggs estimate.

Uyeno-Hamilton-Biggs also estimate that the NDSI for condominiums is 0.90%. As one would expect, the estimated NDSI for vacant land is much higher – 1.66%.

We now shift to air pollution. Air pollutants are emitted from many sources, especially motor vehicles, industrial plants and power plants.[16] 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 μ in diameter (PM10). VOCs combine with NO_x to produce ozone which is a primary contributor to morbidity (illness). Through chemical reactions SO_x, as well as 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 cause 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 (Pearce and Turner 1990). 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, which experts suggest will raise temperatures approximatel 3 °C (+ or – 1.5 °C) in about a century (Schelling 1992). Cline (1992) estimates global temperatures will rise by 10 °C over the next three hundred years.

As just indicated, air pollution results in many health costs and non-health costs. The health cost of air pollution includes the costs of premature death, and the costs of morbidity. Non-health 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.

One approach for 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 – for example, 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 willingness-to-pay estimates. A very different and frequently used approach involves the estimation of hedonic property value models.

Krupnick (1995) provides recent estimates of the annual health costs per person attributable to PM10, sulfure dioxide, lead and ozone, based on

[16] In the USA, Germany and the UK, SO_x emissions are primarily from power stations (about 60%) and industrial plants (about 25%), and NO_x emissions are primarily from transportation (30–45%) and from power stations (30–45%) (Pearce and Turne 1990, p. 192). Quoting from the U.S. EPA, Ogawa (1992) states "[o]ver the past century, fossil fuel burning was responsible for an estimated 57% of CO_2 emissions..." Krupnick and Portney (1991) indicate that "[m]ore and more, air pollution problems are those associated with wood stoves, small dry-cleaning and degreasing operations, painting shops, bakeries, and other decentralized sources."

dose response functions. These estimates, which appear in Table 2, include both morbidity and mortality costs, except for SO_2 which includes only mortality costs. With the exception of ozone, mortality costs dominate. The ranges reported in Table 2 may be viewed as 95% confidence intervals derived from Monte Carlo simulations.

Smith and Huang (1995) recently conducted a meta-analysis of 86 hedonic property value estimates from 37 different studies conducted between 1967 and 1988. Each of these studies attempted to measure the impact of a one-unit change in total suspended particulates (TSP) on the asset value of a typical house in one or more cities. The mean estimate in $163 per house per microgram per cubic meter (1994 dollars). However, Smith-Huang note that this value is inflated due to a few outliers. Indeed, the median value of the 86 estimates is only $33 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 (1995, p. 223) 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.” 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.

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 2 also presents estimates of the annual cost of adding one ton of various types of pollutants to the air. Small and Kazimi (1994) recently reported such estimates for the Los Angeles area. Their 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 urban areas. These 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-Kazimi’s findings indicate that most of the costs of air pollution result from premature death, rather than from illness. Because 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-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 million (in 1994 prices). Earlier we suggested that a value about half as high may be more appropriate.[17] Use of

[17] Indeed, Krupnick and Portney (1991) argue that smaller value of life estimates than those found in the literature should be used in estimating the costs of air pollution because air pollution mainly results in the premature deaths of older persons, that is, persons with considerably shorter life expectancies than average members of the population.

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 μg 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 cause Small and Kazimi's baseline estimates to fall proportionately.

In an interesting extension, Small and Kazimi 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 are predicted to fall to 1.7 cents and 37 cents (in 1994 dollars), respectively, by the year 2000 as newer, less polluting vehicles replace 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. Taxes typically result in a deadweight loss. 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. Lindbeck (1986) suggests that the most 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.

As a consequence of the deadweight loss, the social cost of raising a dollar of revenue through a tax is not \$1 but $\$(1+\text{MEB}) > \$1$, where MEB is the marginal excess burden of taxation or the shadow cost of public funds. In cost-benefit analysis, government revenues and expenditures should be multiplied by (1+MEB). Projects with positive but low NPVs calculated without this adjustment might well turn negative after such an adjustment.

Several studies provide estimates of MEB for specific taxes and countries. They assume "reasonable" values of key parameters and then simulate the efficiency costs. Estimates for the United States have been provided by Browning (1976), Hausman (1981), Browning and Johnson (1984), Stuart (1984), Ballard et al. (1985a, b), Browning (1987), Ballard (1988) and Jorgenson and Yun (1990). Estimates have been provided for other countries by, for example, Stuart (1981) and Hanson and Stuart (1985) for Sweden, Campbell (1975) for Canada, and Diewert and Lawrence (1994, 1996) for New Zealand.

MEBs vary according to the type of tax. In general, MEBs are greater when the taxed activity is more elastic. The MEBs from income taxes are higher than the MEBs from property taxes and sales taxes. Table 2 provides range estimates for a number of important tax "types": all taxes, income taxes, sales taxes and property taxes. The ranges are derived from Ballard, Shoven and Whalley (1985 a, b) and Jorgenson and Yun (1990), with the former generally obtaining lower estimates than the latter. Ballard-Shoven-Whalley estimate the MEB 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. Under a similar set of assumptions, Jorgenson and Yun estimate the MEB for all taxes is 46 cents per dollar.

Diewert and Lawrence (1994) provide estimates of the MEB for different sectors in New Zealand. Their estimated MEBs for 1991 were $ 0.14 for general consumption taxation and $ 0.18 for labor taxation, which are lower than the values obtained for United States. Interestingly, they find that for automobiles the MEB 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 MEB is relevant to policy analysis? With respect to federal projects, it is probably reasonable to view income taxes as the marginal tax source, suggesting that the appropriate MEB 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 MEB of around $ 0.17.

4. Transferring and adjusting plug-in values

Most of the estimates in Table 2 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, the values in Table 2 should be adjusted depending on the specifics of a particular application.[18] Here we briefly review four sets of factors that should be considered: differences in socioeconomic and other personal characteristics of the population (e.g. income and age), differences in physical and other characteristics of the jurisdiction (e.g. geographic characteristics), differences in the characteristics of the project itself (e.g. project quality), and temporal changes.

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 (Waters 1994) and people in wealthy districts value the effect of pollution on house prices proportionately more than do those in poor districts (Smith and Huang 1995). Both evidence and economic theory suggests that shadow price estimates should be adjusted upwards for projects that affect people with higher than aver-

[18] Using existing estimates in a new application has been termed “information transfer” (Smith 1988) or “benefit transfer” (Boyle and Bergstrom 1992; Desvousges, Naughton, and Parsons 1992; McConnell 1992). “Benefit function transfer” pertains to the transfer of an entire benefit function to a new application (Loomis 1992; Downing and Ozuna 1996). For a discussion of general issues pertaining to learning from different types of analyses, see Boardman, Mallery and Vining (1994).

age incomes and should be adjusted downwards 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 suggest that the costs and benefits of people in lower income groups should receive greater weight than those of higher income groups.[19]

For the most part, the estimates in Table 2 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 willingness-to-pay. 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.

The second set of factors that may affect the transferability of plug-in values are 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, ceteris paribus.

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 (Desvousges et al. 1992). Policies or projects under evaluation should also be similar to the projects in the studies used to derive the plug-in values in terms of the availability and quality of alternatives.

[19] For an overview, see Boardman, Greenberg, Vining and Weimer (1996, pp. 411–427). Also see Harberger (1978), Feldstein (1972) and Holtmann (1991).

The final set of factors that should be considered are 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, declining supply of accessible recreational areas might increase the value of such activities, while increasing congestion at the sites might decrease their value. 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.

Unfortunately, current research provides little specific guidance about the magnitude of adjustments. Concerning first how the value of life varies with income, one of the most useful sources is Viscusi (1993, Table 2) who shows, for a number of studies, the implicit value of life and the implicit value of life for air travellers who, on average, have higher incomes.[20] Specific advice with respect to how the value of life varies with the risk of the job is scarce. Viscusi (1993) suggests that researchers should look at specific studies with specific risk characteristics [e.g. Thaler and Rosen (1976) for high risk jobs], while Miller (1990, Table 6) shows that current studies provide no systematic empirical evidence that the value of life is monotonically related to risk level.

Waters (1994, 1996) has performed a comprehensive study of the value of travel time saved (VTTS) and has examined how estimates vary with income, time (year of study), country and trip purpose (inter-urban versus commuting or "other"). He suggests that VTTS increases with income but less than proportionately:

$$\mathrm{VTTS}_Y = \left(\frac{Y}{\bar{Y}}\right)^{0.5} \overline{\mathrm{VTTS}} \tag{1}$$

where VTTS_Y is the VTTS of a traveller with income Y, $\bar{Y}$ is the average income level and $\overline{\mathrm{VTTS}}$ is the average VTTS. The relationship between VTTS and other variables is poor. Button (1994) found no statistical relationship between VTTS and other variables. Waters (1996) found that VTTS increases over time (drifting upward at one percentage point per year) and that inter-urban travel has a slightly higher value than trips for other purposes.

Most of the other research pertaining to adjusting plug-ins concerns estimates of recreation benefits (Eade and Moran 1996; Downing and Ozuna 1996; Boyle and Bergstrom 1992, Brookshire and Neil 1992, Desvousges et al. 1992, Smith 1992, Walsh et al. 1992).[21] In these articles, researchers use multiple regression analysis or other multi-variate methods to examine the relationship between a particular plug-in value and one or more of the

[20] These estimates assume an unitary elasticity of income, based on Viscusi and Evans (1990).

[21] See also Smith and Huang (1995), which concerns the cost of increasing total suspended particulates and was discussed earlier.

four factors discussed earlier in this section. For example, Walsh et al. (1992) examine the influence of population characteristics (e.g. socio-economic characteristics and indices of taste), jurisdiction characteristics (e.g. site quality), and characteristics of the methodology used in the original estimation (e.g. contingent valuation method or travel cost method) on the estimated consumer surplus from one activity day of recreation obtained from each study. Smith and Osborne (1996) focus on the relationship between willingness to pay for improving (or maintaining) visibility at the national parks and improving the proportionate change in visibility at the parks, but also consider other explanatory variables. Downing and Ozuna (1996) focus on anglers' willingness to pay for a fishing trip per person. Desvousges et al. (1992) examine the value of water quality improvements. Each study tends to focus on valuing a different impact. Also, the explanatory variables vary from one study to another with variables concerning the estimation methodology often being of primary interest.

The central conclusion for policy purposes is that benefit transfer variables are not yet broadly developed enough to be amenable to being summarised or used to adjust the plug-ins presented in Table 2.

5. Conclusion

We have presented a summary of the shadow price estimates most often needed in policy analysis. Our purpose is to provide some "reasonable numbers." By making such numbers available in one place, we hope to reduce the cost of doing policy analysis, which we hope will, in turn, lead to more analyses. Clearly, we cannot do justice to the complexity of the issues underlying even one of these estimates. These are best handled in the original studies and meta-analyses from which we draw our estimates.

Of course, each estimate should be considered as no better than a "best guess" based on a review of the literature. Estimating shadow prices is not an exact science. Best practice is continually evolving. Therefore, when using the estimates reported in Table 2, analysts should always perform sensitivity analysis.

References

Abdalla CW, Roach BA, Epp DJ (1992) Valuing environmental quality changes using averting expendituers: an application to groundwater contamination. Land Econ 68(2):163–169

Ballard CL (1988) The marginal efficiency cost of redistribution. Am Econ Rev 78(5): 1019–1033

Ballard CL, Shoven JB, Whalley J (1985 a) General equilibrium computations of the marginal welfare costs of taxes in the United States. Am Econ Rev 75(1):128–138

Ballard CL, Shoven JB, Whalley J (1985 b) The total welfare cost of the United States tax system: a general equilibrium approach. Natl Tax J 38(2):125–140

Bates J, Glaister S (1990) The valuation of time savings for urban transport appraisal for developing countries: a review report prepared for the World Bank

Bishop RC (1978) Endangered species and uncertainty: the economics of a safe minimum standard. Am J Ag Econ 60:10–18

Bishop RC, Heberlein TA (1990) The contingent valuation method. In: Johnson RL, Johnson GV (eds) Economic valuation of natural resources: issues, theory, and application. Westview Press, Boulder, CO, pp 81–104

Boardman AE, Greenberg DH (forthcoming) Discounting and the social discount rate. In: Thompson F (ed) Handbook in applied public finance. Marcel Dekker

Boardman AE, Greenberg DH, Vining AR, Weimer DL (1996) Cost-benefit analysis: concepts and practice. Prentice-Hall, Upper Saddle River, NJ

Boardman AE, Mallery WL, Vining AR (1994) Learning from *ex ante/ex post* cost-benefit comparisons: the Coquihalla highway example. Socio Econ Plan Sci 28(2):69–84

Boyle KJ, Bergstrom JC (1992) Benefits transfer studies: myths, pragmatism and idealism. Water Resources Res 28(3):657–663

Boyle KJ, Bishop RC (1987) Valuing wildlife in benefit-cost analysis. Water Resources Res 23(5):943–950

Brookshire DS, Neill HR (1992) Benefit transfers: conceptual and empirical issues. Water Resources Res 23(5):651–655

Browning EK (1976) The marginal cost of public funds. J Pol Econ 84(2):283–298

Browning Ek (1987) On the marginal welfare cost of taxation. Am Econ Rev 77(1):11–23

Browning EK, Johnson WR (1984) The trade-off between equality and efficiency. J Pol Econ 92:175–203

Button KJ (1994) The impacts of transport – what can we learn from meta-analysis? Proceedings, Annual meeting of the transport research forum, Daytona Beach, Florida, pp 171–193

Campbell H (1975) Deadweight loss and commodity taxation in Canada. Can J Econ 8(3): 441–446

Cline WR (1992) The economics of global warming. Institute for International Economics, Washington DC

Cummings RG, Brookshire DS, Schulze WD (1986) Valuing environmental goods: an assessment of the contingent valuation method. Rowman & Allanheld, Totowa, NJ

Desvousges WH, Naughton MC, Parsons GR (1992) Benefit transfer: conceptual problems in estimating water quality benefits using existing studies. Water Resources Res 28(3):675–683

Desvousges WH, Smith VK, Fisher A (1987) Option price estimates for water quality improvements: a contingent valuation study for the Monongahela River. J Env Econ Mgmt 14(2):248–267

Diewert WE, Lawrence DA (1994) The marginal costs of taxation in New Zealand. Report prepared by Swan Consultants, Canberra

Diewert WE, Lawrence DA (1996) The deadweight costs of taxation in New Zealand. Can J of Econ 29:S658–S673

Downing M, Ozuna T Jr (1996) Testing the reliability of the benefit function transfer approach. J of Environ Econ & Mgmt 30:316–322

Feldstein MS (1972) Distributional equity and the optimal structure of public prices. Am Econ Rev 62(1):32–36

Fisher A, Chestnut LG, Violette DM (1989) The value of reducing risks to death: a note on new evidence. J Pol Anal & Mgmt 8(1):88–100

Forslund UM, Johansson B (1995) Assessing road investments: accessibility changes, cost benefit and production effects. Ann Reg Sci 29(2):155–174

Hanley ND (1989) Valuing non-market goods using contingent valuation. J Econ Surveys 3(3):235–252

Harberger AC (1978) On the use of distributional weights in social cost-benefit analysis. J Pol Econ 86(2):S87–S120

Hausman JA (ed) (1993) Contingent valuation: a critical assessment. North Holland, New York

Holtmann AG (1991) Beyond efficiency: economics and distributional analysis. In: Weimer DL (ed) Policy analysis and economics. Kluwer Academic, Boston, MA, pp 45–64

Jordan JL, Elnagheeb AH (1993) Willingness to pay for improvements in drinking water quality. Water Resources Res 29(2):237–245

Jorgenson DW, Yun K-Y (1990) Tax reform and US economic growth. J Pol Econ 98(5): S151–S193

Krupnick AJ (1995) The implementation and enforcement of the clean air act amendments of 1990. Testimony before the subcommittees on oversight and investigations and on health and the environment of the committee on commerce. US House of Representatives, Thursday, Nov 9, 1995
Krupnick AJ, Portney PR (1991) Controlling urban air pollution: a benefit-cost assessment. Science 252(26):522–528
Lawson JJ (1989) The value of passenger travel time for use in economic evaluation of transport investments. Transport Canada, Ottawa, Ont
Lind RC et al (1982) Discounting for time and risk in energy policy. Resources for the Future, Washington DC
Lindbeck A (1986) Limits to the welfare state. Challenge 31–36
Long DA, Mallar CD, Thornton CV (1981) Evaluating the benefits and costs of the jobs corps. J Pol Anal & Mgmt 1(1):55–76
Loomis JB (1992) The evolution of a more rigorous approach to benefit transfer: benefit function estimation. Water Resources Res 28(3):701–705
Luken RA; Johnson FR, Kibler V (1992) Benefits and costs of pulp and paper effluent controls under the clean water act. Water Resources Res 28(3):665–674
Lyon RM (1990) Federal discount rate policy, the shadow price of capital, and challenges for reforms. J Env Econ & Mgmt 18(2):S29–S50
Max W, Rice DP (1993) Shooting in the dark: estimating the cost of firearm injuries. Health Affairs 12(4):171–185
McConnell KE (1992) Model building and judgment: implications for benefit transfers with travel cost models. Water Resources Res 28(3):675–683
Miller TR (1989a) The value of time and the benefit of time saving. Presented to the national roads board, New Zealand, and the federal highway administration. US Dept of Transportation. Urban Institute, Washington DC
Miller TR (1989b) Narrowing the plausible range around the value of life. The Urban Institute, Washington DC
Miller TR (1990) The plausible range for the value of life – red herrings among the mackerel. J Forensic Econ 3(3):17–39
Miller TR (1993) Costs and functional consequences of US roadway crashes. Accident Anal and Prev 25(5):593–607
Miller TR, Cohen MA, Rossman SB (1993) Victim costs of violent crime and resulting injuries. Health Affairs 12(4):186–197
Mitchell RC, Carson RT (1989) Using surveys to value public goods: the contingent valuation method. Resources for the Future, Washington DC
Mohring H, Schroeter J, Wiboonchutikula P (1987) The values of waiting time, travel time, and a seat on a bus. Rand J Econ 18(1):40–56
Moulton BR (1996) Bias in the consumer price index: what is the evidence. J Econ Persp 10(4):159–177
Nelson J (1980) Airports and property values: a survey of recent evidence. J Transport Econ & Pol 14(1):37–52
O'Byrne PH, Nelson JP, Seneca JJ (1985) Housing values, census estimates, disequilibrium and the environmental cost of airport noise: a case study of Atlanta. J Env Econ & Mgmt 12(2):169–178
Ogawa Y (1992) Economic activity and the greenhouse effect. The Energy J 12:23–35
Pearce DW, Turner RK (1990) Economics of natural resources and the environment. The Johns Hopkins University Press, Baltimore, MD
Pennington G, Topham N, Ward R (1990) Aircraft noise and residential property values adjacent to Manchester International Airport. J Transpt Econ & Pol 24(3):49–59
Rice DP, MacKenzie EJ, Assoc (1989) 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
Rosenthal DH, Nelson RH (1992) Why existence value should *not* be used in cost-benefit analysis. J of Policy Anal and Mgmt 11(1):116–122
Schelling TC (1992) Some economics of global warming. Am Econ Rev 82(1):1–14

Sharp C (1988) Developments in transport policy, the value of time savings and of accident prevention. J Transport Econ & Pol 22(2):235–238
Small KA, Kazimi C (1994) On the costs of air pollution from motor vehicles. Department of Economics, Paper No 94-95-3. University of California, Irvine
Smith VK (1992) On separating defensible benefit transfers from “smoke and mirrors”. Water Resources Res 28(3):685–694
Smith VK, Desvousges WH (1986) Measuring water quality benefits. Kluwer-Nijhoff Publishing, Boston, MA
Smith VK, Desvousges WH, Fisher A (1984) A comparison of direct and indirect methods for estimating environmental benefits. Working Paper 83-W32, Vanderbilt University, Nashville, Tennessee
Smith VK, Huang J-C (1995) Can markets value air quality? A meta-analysis of hedonic property value models. J Pol Econ 103(1):209–227
Smith VK, Osborne LL (1996) Do contingent valuation estimates pass a “scope” test? A meta-analysis. J Environ Econ & Mgmt 31:287–301
Sorg CF, Loomis JB (1984) Empirical estimates of amenity forest values: a comparative review. General Technical Report RM-107, Fort Collins, CO; Rocky Mountain Forest and Range Experiment Station, Forest Service, USDA
Stevens TH, Echeverria J, Glass RJ, Hager T, More TA (1991) Measuring the existence value of wildlife. Land Econ 67(4):390–400
Stuart CE (1981) Swedish tax rates, labor supply, and tax revenues. J Pol Econ 89(5):1020–1038
Stuart CE (1984) Welfare costs per dollar of additional tax revenue in the United States. Am Econ Rev 74(3):452–462
Texas Transportation Institute (1990) Value of time and discomfort costs, progress report on literature review and assessment of procedures and data. Technical Memorandum for NCHRP, pp 7–12
Thaler R, Rosen S (1976) The value of saving a life: evidence from the market. In: Terleckyi NE (ed) Household production and consumption. NBER, Cambridge, MA, pp 265–298
Townroe P, Dabinett G (1995) The evaluation of public transport investments within cities. Ann Reg Sci 29(2):175–188
Uyeno D, Hamilton SW, Biggs AJG (1993) Density of residential land use and the impact of airport noise. J Transport Econ & Pol 27(1):3–18
Viscusi WK (1993) The value of risks to life and health. J Econ Lit 31(4):1912–1946
Viscusi WK, Evans WN (1990) Utility functions that depend on health status: estimates and economic implications. Am Econ Rev 80(3):353–374
Walsh RG, Johnson DM, McKean JR (1992) Benefit transfer of outdoor recreation demand studies, 1968–1988. Water Resources Res 28(3):707–713
Waters WG II (1994) The value of travel savings and the link with income: implications for public project evaluation. Intl J Transport Econ 11(3):243–253
Waters WG II (1996) Values of travel time savings in road transport project evaluation. In: Hensher D, King J, Oum T (eds) World Transport Research, Proceedings of the 7th World Conference on Transport Research, Vol 3. Elsevier, New York
Willis KG (1990) Valuing non-market wildlife commodities: an evaluation and comparison of benefits and costs. Applied Econ 22(1):12–30