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Some Conceptual and Methodological Issues in the Analysis of the Social Cost of Motor-Vehicle Use

October 2004

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SOME CONCEPTUAL AND METHODOLOGICAL ISSUES IN THE ANALYSIS OF THE SOCIAL COST OF MOTOR-VEHICLE USE

Report #2 in the series: *The Annualized Social Cost of Motor-Vehicle Use in the United States, based on 1990-1991 Data*

UCD-ITS-RR-96-3 (2)

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LIST OF ACRONYMS AND ABBREVIATIONS AND OTHER NAMES

The following are used throughout all the reports of the series, although not necessarily in this particular report

AER = *Annual Energy Review* (Energy Information Administration)
AHS = *American Housing Survey* (Bureau of the Census and others)
ARB = Air Resources Board
BLS = Bureau of Labor Statistics (U. S. Department of Labor)
BEA = Bureau of Economic Analysis (U. S. Department of Commerce)
BTS = Bureau of Transportation Statistics (U. S. Department of Transportation)
CARB = California Air Resources Board
CMB = chemical mass-balance [model]
CO = carbon monoxide
dB = decibel
DOE = Department of Energy
DOT = Department of Transportation
EIA = Energy Information Administration (U. S. Department of Energy)
EPA = United States Environmental Protection Agency
EMFAC = California's emission-factor model
FHWA = Federal Highway Administration (U. S. Department of Transportation)
FTA = Federal Transit Administration (U. S. Department of Transportation)
GNP = Gross National Product
GSA = General Services Administration
HC = hydrocarbon
HDDT = heavy-duty diesel truck
HDDV = heavy-duty diesel vehicle
HDGT = heavy-duty gasoline truck
HDGV = heavy-duty gasoline vehicle
HDT = heavy-duty truck
HDV = heavy-duty vehicle
HU = housing unit
IEA = International Energy Agency
IMPC = Institutional and Municipal Parking Congress
LDDT = light-duty diesel truck
LDDV = light-duty diesel vehicle
LDGT = light-duty gasoline truck
LDGV = light-duty gasoline vehicle
LDT = light-duty truck
LDV = light-duty vehicle
MC = marginal cost
MOBILE5 = EPA's mobile-source emission-factor model.
MSC = marginal social cost
MV = motor vehicle
NIPA = National Income Product Accounts
NO_X = nitrogen oxides
NPTS = Nationwide Personal Transportation Survey
OECD = Organization for Economic Cooperation and Development

O_3 = ozone
OTA = Office of Technology Assessment (U. S. Congress; now defunct)
PART5 = EPA's mobile-source particulate emission-factor model
PCE = Personal Consumption Expenditures (in the National Income Product Accounts)
PM = particulate matter
PM_{10} = particulate matter of 10 micrometers or less aerodynamic diameter
$PM_{2.5}$ = particulate matter of 2.5 micrometers or less aerodynamic diameter
PMT = person-miles of travel
RECS = Residential Energy Consumption Survey
SIC = standard industrial classification
SO_x = sulfur oxides
TIA = *Transportation in America*
TSP = total suspended particulate matter
TIUS = *Truck Inventory and Use Survey* (U. S. Bureau of the Census)
USDOE = U. S. Department of Energy
USDOL = U. S. Department of Labor
USDOT = U. S. Department of Transportation
VMT = vehicle-miles of travel
VOC = volatile organic compound
WTP = willingness-to-pay

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2. SOME CONCEPTUAL AND METHODOLOGICAL ISSUES IN THE ANALYSIS OF THE SOCIAL COST OF MOTOR-VEHICLE USE

2.1 THE SOCIAL COST OF MOTOR-VEHICLE USE IN 1990, OR THE ANNUALIZED COST OF MOTOR-VEHICLE USE, BASED ON 1990 DATA?: DIFFERENT ANALYTICAL FRAMEWORKS

We start with the presumption that it is most useful, and most typical, to estimate social cost over some unit of time -- most typically, a year. Given this, there are at least three different frameworks one can estimate the social cost (either the average cost or the marginal cost): 1) as the costs that would not have been incurred in a given year had investment in and use of motor-vehicles and highways ceased at the beginning of the year; 2) as the costs that would not have been incurred in a given year had investment in and use of motor-vehicles and highways ceased many years before the given year; 3) as the yearly (annualized) costs that would not be incurred in the future as a result of ceasing to invest in and use motor-vehicles and highways.

2.1.1 Present value method 1: the social cost of motor-vehicle use in 1990

Analyses of the private or social costs of transportation often estimate costs for a particular year (see studies cited in Report #3 and #5). In general, it does seem natural, when estimating the social cost of transportation, to estimate it *for* a particular year. But what exactly do we mean by the social cost of motor-vehicle use in, say, 1990? If we accept the opportunity-cost definition of "cost" (which we do here), and accept, semantically, that when we say "in 1990," we exclude costs incurred in other years, then we must mean all costs incurred in 1990 (not in 1989 or 1991) that would not have been incurred had there been no motor-vehicle use. It turns out, though, that it matters *when* motor-vehicle use is assumed to have been eliminated: as we shall see, the costs foregone in 1990 as a result of a no-motor-vehicle policy adopted January 1, 1990 are not the same as the costs foregone in 1990 as a result of a no-motor-vehicle policy that stopped motor-vehicle investment and use, say, 30 years earlier. (The difference, as we shall see, has to do with the treatment of interest payments.) We will consider two cases: one in which investment in and use of motor-vehicles and highways and related services ceased on January 1 of 1990, and one in which it ceased so long prior to 1990 that no vehicle or highway stock would have remained in 1990. The second interpretation, which we consider the more awkward, is considered in the next section. Here, we will consider the case of eliminating motor-vehicle use on January 1, 1990.

Imagine a policy, adopted on January 1, 1990, that summarily eliminated motor-vehicle use[1]. The relevant question then becomes: *What costs would have been saved in 1990, as a result of the hypothetical policy, compared to what actually happened?* It is most appropriate to answer this question in present-value terms; that is, to estimate the present value on the day of the policy, January 1, of all of the costs that would have

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[1]That there never could have been and never will be such a policy is beside the point; as discussed above, we either would use an estimate of the cost of all motor-vehicle use to calculate an average cost rate to estimate policy-relevant marginal costs, or, better, apply the analytical methods and data to a marginal analysis.

been foregone over the course of the year as a result of the policy. Thus, one would estimate month-by-month, or even day-by-day, capital and operating expenditures related to motor-vehicle use over 1990, and discount them back to the beginning of the year[2]. One would not count the value of capital (such as motor-vehicles and highways) in existence as of January 1 1990, because those capital expenditures would not have been avoided as a result of the January 1 policy. (Of course, some of the existing capital could have been liquidated, but this would have been a one-time opportunity, available only in one year [unless one assumed that the recovered investment would have been amortized over a period of years], not every year. That is, we would reap the benefits of the total liquidation once, not in each year, and so should not include these benefits in an analysis that might be used to represent costs saved each and every year.)

Now turn to interest payments. Suppose that, in actuality in 1990, a person spent $10,000 on a vehicle on January 1. Suppose further that given the hypothetical no-motor-vehicle-use law, the person would have invested the $10,000 on January 1 at annual interest rate i of 8%. At the end of 1990, the person would have had $10,800. But what would have been the present value on January 1 of that $10,800? Just $10,800/(1+r), where r is the social discount rate. If r = i, then the present value of the investment will equal the initial investment. That is, if r = i, there is no additional interest "cost" to add on to the beginning-of-year principal, because the interest is incurred later, and the rate at which the interest accrues is exactly canceled by the rate at which it is disvalued for being in the future rather than the present (when r = i). In an economy with no transaction costs, equal risks everywhere, perfect information and access to markets, and perfectly (costlessly and instantly) mobile capital, one would expect there to be only one interest rate prevailing. In a real economy, however, there will be many interest rates, and no reason to expect that the interest rate relevant to investment in motor vehicles and highways should be the same as the social discount rate[3]. (What the social discount rate should be is another question) In any event, the point is that in a present-value analysis the interest-cost component of the social cost is not simply some interest rate multiplied by the outstanding principal; rather, it is that number *discounted* by the social discount rate[4]. This is true regardless of what one assumes about the course of investment (e.g., whether monthly, or all at once in the middle of the year): the key point about the interest cost is that it is incurred *later* than

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[2]As a practical matter, it probably is not worth doing this discounting, because, if the expenditures on new capital and operation do not vary much from month to month, then the discounted present value of a cost stream over a year differs from the simple sum of the periodic costs over a year by about only 1/2 the annual discount rate -- that is, if the annual discount rate is 8%, the simple (undiscounted) sum of the periodic costs over a year is about 4% higher than the discounted present value of the cost stream over a year. (One also could argue that, if the object of estimating costs in 1990 is to get an idea of the costs incurred every year -- that is, if 1990 is meant represent a periodic annual payment -- then the relevant time unit is one year, and the question of discounting *within* a year is obviated.) Of course, to be consistent, one would have to treat interest payments the same way.

[3]In fact, at a minimum, there always will be a real resource cost to establishing and operating financial markets.

[4]The argument is the same, of course, if one imagines that the person took out a one-year automobile loan at 8%, so that at the end of the year, the person paid $10,800. This amount has a present value on January 1 of $10,800/(1+r).

the initial-investment cost, and in a present-value analysis the disvalue of "later" tends to cancel (and may exactly cancel) the value of the interest[5].

In sum, we believe that the best way to answer the question "what was the social cost of motor-vehicle use in 1990?" (which, incidentally, is not the question that we ask here) is to estimate the present value of all capital and operating expenditures incurred throughout the year, and ignore interest payments, the value of pre-existing capital, and interest on pre-existing capital. Perhaps the key aspect of this particular way of framing and answering the question is that interest payments are not counted as costs (if $i = r$). This of course is an inevitable feature of any present-value analysis. The problem, though, is that present value of social cost *in one year* is not a normal present-value calculation, because it is limited to one year, whereas present-value analyses normally consider the entire future stream of costs. Yet, neither is the one-year present-value analysis equivalent to an annualized-cost analysis. Thus the problem with the approach ("the social cost of motor-vehicle use in 1990:" one-year present value): it is neither a true-present value analysis (which would include the present value of all costs over all years throughout the "life" of the analysis) nor a true annual-cost analysis (which would annualize all costs over the life of the analysis). Because it excludes (actually, discounts) interest costs, it is not even equivalent to the cost in any one year of an annualized-cost analysis.

The upshot, then is that this one-year present-value formulation, which we believe is the most logical way to frame the question "what was the social-cost of motor-vehicle use in 1990?," is atypical and even misleading analytically. Because of this, we have discarded the one-year present-value framework. Along with it, we have discarded the question "what was the social-cost of motor-vehicle use in 1990?," because we believe that no interpretation of the question other than the one-year present-value interpretation is reasonable. *Consequently, in this analysis we do not answer or even ask the question "what was the social cost of motor-vehicle use in 1990?".* As discussed in section 2.1.3, we ask, and answer, a different question.

2.1.2 Present-value method 2: the social cost of motor-vehicle use in 1990, in a parallel world

As an alternative to the present-value formulation just discussed, one could estimate the motor-vehicle related costs that would not have been incurred in 1990 had investment in motor-vehicles and infrastructure ceased long enough ago that by 1990 there was no remaining capital at all. Thus, the hypothetical saving in 1990, compared to the actual situation in 1990, would have been the actual capital and operating expenditures in 1990, plus the foregone returns to all the motor-vehicle related capital invested in the *previous* years. That is, had we long prior to 1990 stopped using and investing in motor vehicles, then in 1990 we would still have had available not only the money that we actually did spend on motor-vehicle capital and operation in 1990, but also the returns to the alternative investments we would have made [but actually did not] over the prior years. We will call this the "parallel world" formulation of the

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[5]The situation is similar regarding interest that could be earned on pre-existing capital. If one assumed that the investment existing as of January 1 1990 could have been fully liquidated at its depreciated value, then one would have recouped not only the remaining undepreciated investment, but also the opportunity to generate new income from the newly reclaimed investment. This additional interest income from the re-investment of money from the liquefied capital would have to be discounted back to January 1.

problem: in the parallel world in which motor-vehicle use ceased long ago, they did save capital, operating, *and interest* costs (related to previous investments) in 1990.

Note that in this framework and the previous one, interest on the investments made *in 1990* is not counted because it is discounted back to January 1 1990 at the rate at which it accrues (if i=r). The major difference between this "parallel-world" framework and the preceding one is that in this framework there is interest from investments made in the years prior to 1990. As we saw above, the present value on January 1, 1990, of $10,000 invested on January 1, 1990 and allowed to accrue interest over the year is just $10,000, if the interest-accrual rate i equals the social discount rate r. But the present value on January 1, 1990 of $10,000 invested on January 1, 1989, and allowed to accrue interest through December 31, 1990 is $\$10,000 * (1+i)^2/(1+r) = \$10,000 * (1+i)$ [if i=r]; or, the original investment plus an interest payment equal to i * $10,000. This interest payment, on the prior-year investment, is a cost in the parallel-world formulation. It is not in the previous formulation, and that is the difference between the two.

A serious practical problem with the parallel-world formulation is that it can not represent the costs of anything that we can actually *do* (whether marginally or not). Because it is contingent upon history being other than it was, it cannot possibly represent the cost of any policy that we might actually now enact. In other words, we can never be in the parallel world, because by definition the parallel world always diverges from this one in the past (of both). Another, related awkwardness is that it looks at costs in one year that are attributable to hypothetical actions in an earlier year. If a social cost estimate is to be relevant to actions that we can take now, rather than to actions already taken, then a different formulation is needed.

2.1.3 The annualized cost method: the annualized social cost of motor-vehicle use (based on 1990-1991 data)

Rather than estimate the cost of motor-vehicle use "in" a particular year, and run up against the difficulties discussed previously, I estimate the annualized cost of motor-vehicle use on the basis of activity, annual expenditures, and the value of capital stock in a particular year. The annualized cost of motor-vehicle use, based on 1990-1991 data, is equal to the sum of:

- 1990-1991 periodic or "operating" costs, such as fuel, vehicle maintenance, highway maintenance, salaries of police officers, travel-time, noise, injuries from accidents, and disease from air pollution; plus
- the 1990-91 replacement value of all capital, such as highways, parking lots, and residential garages (items that provide a stream of services), converted into an equivalent stream of annual costs (annualized) over the life of the capital, on the basis of real discount rates (see the discussion on discount rates, below).

This annualization method -- whereby the total yearly cost is equal to periodic "operations and maintenance costs" plus annualized capital replacement costs -- is just the obverse of evaluating the net present value of alternative investment options (in transportation or any other arena). In essence, the yearly social-cost of motor vehicle use, as we estimate it, is the yearly cost stream of the whole motor-vehicle system, analyzed as if it were one large transportation alternative among several[6]. Of course, the *scale* that I have chosen -- all motor-vehicle use -- is just a convenient point of reference. It is most useful to view the analysis presented here as an analysis of a generic motor-vehicle-use project, or alternative, scaled up to the level of all motor vehicle use in the U. S.

There is no coherent alternative to the annualization approach (or, what is equivalent, the net-present-value approach) to estimating the social cost. Either one performs a social-cost analysis as a project evaluation, or one doesn't have a well-defined analysis[7]. If (somehow) we fail to amortize capital costs, or do so incorrectly, or in general don't treat capital and operating costs in an economically consistent fashion, we will not have economically meaningful results, and might then incorrectly evaluate alternatives or mis-price goods and services.

The method formally. The annualization (or amortization) of the capital investment produces a stream of fixed annual payments whose present value is equal to the initial investment. The annualized capital costs -- not the straight capital expenditures -- are added to annual operating and maintenance costs to produce the total annualized cost[8]. One must annualize capital costs -- or, what is equivalent, estimate the present value of a stream of periodic costs -- because, fundamentally, the social value of a stream of costs or services depends on how the costs and benefits are distributed over time: usually we prefer to enjoy the benefits now and pay the costs later, rather than the other way around.

In this analysis of the total social cost of motor-vehicle use, the pertinent capital cost is the replacement cost of the entire capital stock, and the pertinent operating and maintenance cost is that for the entire capital stock. To estimate the replacement value of the entire capital stock, I assume that the annual capital outlay replaces some fraction of the stock, and then scale up the annual expenditure accordingly[9].

Formally:

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[6]Least-cost electricity planning, after which some analysts hope to be able to model transportation planning, is based on annualized $-per-kWh costs.

[7]One can estimate the net present value rather than the annualized cost of a project, but these are economically equivalent methods.

[8] For three reasons, the simple sum of annual capital expenditures and annual O & M expenditures is not an economically useful estimate of cost. First, as discussed below, expenditures do not necessarily represent costs, although I assume that they do. Second, the O & M expenditures pertain to the entire existing capital stock, whereas the current annual capital expenditure represents but a portion of the total replacement value of the existing capital stock. Third, O & M resources are assumed to be consumed within a year, whereas capital is consumed over many years.

[9]Given a series of yearly capital expenditures, there are in general two ways to estimate the total value of in-place capital stock. First, if the series includes the initial investments in the entire stock, one simply can add these initial expenditures. Second, if the series includes ongoing annual replacement costs, one can multiply these annual costs by the life of the investment. If unit cost, investment lifetime, and facility size remain constant, then the annual investment replacement cost multiplied by the investment lifetime will equal the initial total investment cost.

$$AC = ACC + OMC$$

$$ACC = \frac{NRV \cdot i}{1 - (1 + i)^{-t}}$$

$$NRV = RV - RV \cdot s \cdot (1 + i)^{-t}$$

$$RV = \frac{ACE}{ARF}$$

where:

AC = the annualized cost of the government infrastructure or service
ACC = the annualized capital cost: a fixed annual amount, or annuity, such that the present value of a stream of t such amounts paid at the end of each period (year) is equal to the net replacement value (NRV) of the capital at the beginning of the first period (t = 0)
OMC = the annual operating and maintenance cost
NRV = the replacement value of the capital stock, net of the present value of the salvage value of the capital, at the beginning of the first period (t = 0)
RV = the replacement value of the capital stock
s = the salvage value of the capital, expressed as a fraction of RV (I assume that s = 0, which means that NRV = RV)
i = the discount rate
t = the life of the capital: the number of periods that the capital provides services without major reinvestment
ACE = annual capital expenditures
ARF = annual capital replacement factor: the fraction of the total capital stock that is replaced each year by the annual capital expenditure ACE

The capital value, the life of the capital, and the assumed maintenance and repair costs must be internally consistent. That is, one must consider the life of the capital to be the period of time between the initial capital investment and the next equivalent investment given ongoing maintenance and repair of the capital stock.

Generally, one distinguishes land from other capital, because land yields services in perpetuity. Land is not "consumed;" rather, at the end of a project it is as available for other uses as it was at the beginning of the project. Hence, the life t is infinite, and for land the annualization formula simplifies to:

$$ACC_{Land} = TV_{Land} \cdot i$$

where:

TV_{Land} = the total value of the total land stock, analogous to the replacement value of the total capital stock.

I estimate the total value of land by scaling the annual vale of land used for new capital projects to the level of the entire land stock. The annual value of land used for new capital projects is estimated as a fraction of annual total capital expenditures.

Note that amortization formula annualizes the entire replacement value at t=0, which means conceptually that the entire capital stock is replaced overnight. Of course, we do not really replace the entire capital stock overnight, or all in one year; rather, we replace capital gradually, as it is worn out. But in the long run, the annualized cost of replacing the existing capital gradually is the same as the annualized cost of replacing it all at once. If capital has a life of *n* years, and every year *1/nth* of the capital stock is replaced, then the cost, calculated today, of each future *1/nth* capital replacement is an annualized cost stream equal to *1/nth* the annualized cost of replacing the entire capital stock. These yearly annualized cost streams accumulate for *n* years, at which point we will have turned over the entire capital stock and will have accumulated *n* annualized cost streams each *1/nth* the annualized cost of replacing the entire capital stock all at once.

Note, though, that if the existing capital can be liquidated such that the full value of the remaining service life of each 1/nth "piece" is recovered (i.e., such that the recoverable value is equal to the present value of the remaining original annuity payments), then the annualized liquidation value, added to annualized cost of replacing the capital as it is worn out, is the same as the annualized cost of immediately replacing the entire stock.

Thus, there are three ways to interpret our estimate of the annualized cost:

i) as the annualized cost, beginning today, of replacing the entire capital stock immediately;

ii) as the annualized cost in the long run (after n years, where n is the life of the capital) of continuing to replace capital as it is normally worn out; or

iii) as the annualized cost, beginning today, of continuing to replace capital as it is normally worn out, *and* of failing to fully liquidate the capital in place.

2.1.4 Concluding remark

In a sense, the question of the appropriate analytical framework really is a question of the appropriate way to handle interest payments. Interest payments are important because a large portion of the total social cost of motor-vehicle use is spent on relatively long-lived equipment and infrastructure: motor-vehicles, garages, parking facilities, highways, and buildings that house administrators, police, regulators, and so on.

2.2 PRICE TIMES QUANTITY VERSUS THE AREA UNDER A SUPPLY CURVE

Our objective is to estimate the social cost of motor-vehicle use. As mentioned in Chapter 1, the total cost of motor-vehicle use is the area under the social-cost curve, S* of Figure 2-1. This is region O-x*-Q* in Figure 2-1. This area, and the social cost, also can be defined as the equilibrium quantity Q* multiplied by the average cost. Put another way, the average cost is that cost which when multiplied by Q* produces a total cost equal to the area under the supply curve S*. If we can estimate the average cost of each cost item, we can multiply it by the quantity of each item supplied, and sum to get the total social cost.

However, in some cases it is difficult to estimate the average cost. Generally, if prices are available (as they are for the priced items of Table 1-1 of Report #1), it is much simpler to use *them*. The problem with doing so is that, in theory, the market-clearing price is equal not to the average cost, but to the marginal cost of the last unit produced to satisfy demand. Assuming a rising marginal-cost curve S* (a supply curve, or "willingness-to-supply" curve), as in Figure 2-1 -- that is, assuming that it costs more to produce the next unit than the previous one -- the marginal cost of the last unit, and hence the price, will be greater than the average cost. This means that the market-clearing price (P*) multiplied by the equilibrium quantity demanded (Q*) will be greater than the average cost multiplied by Q*. In other words, revenue (region O-P*-x*-Q* of Figure 2-1) will exceed total cost (region O-x*-Q*). This can be seen readily in Figure 2-1.

The difference between total revenues and total cost -- region O-P*-x* -- is called the "producer surplus". It is the surplus of revenue over cost; the amount of revenue in excess of the minimum amount that would have been necessary to induce supply[10].

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[10]The minimum amount of revenue necessary to elicit supply -- the minimum "willingness-to-supply" revenue -- is called the producer's cost because it is a function of such things as the minimum acceptable wage compensation (including compensation to the owner of the firm) and the minimum acceptable return on investment, which theoretically are equal to the compensation and return in the next best alternative. That is, willingness to supply, or producer cost, is a function of foregone business opportunities, and does not correspond to a fixed, independently determined rate of return (e.g., 10%) or level of compensation. In an economy that is generally poor but has a few spectacular opportunities, producers generally will expect (be willing to supply at) relatively modest rates of return, and the few exceptions of large returns thereby will constitute a large producer surplus. In short, producer surplus is relative to expectations, which can fluctuate, and not to some fixed benchmark. Put another way, expectations shape opportunity costs.

Producer surplus exists whenever some producers own lower-cost resources or factors than do others. The clearest example today might be oil: some producers, most notably those in the Middle East, own oil that is light, non-viscous, and close to the surface, and hence inexpensive to produce; others, such as some of those in the U.S., own oil that is viscous and far below the surface and expensive to produce. If world demand is high enough that people are willing to pay a price that covers the costs of producing the deep viscous U. S. oil, then the world price will greatly exceed the cost to the Middle-East producers, who consequently will enjoy handsome revenues in excess of their economic cost.

I emphasize two things about producer surplus: first, that it is revenue in excess of true resource cost, and second, that it is not merely a short-term phenomenon or the result of a market failure. Producer surplus can exist in perfect markets in the long-run equilibrium. If some suppliers are willing to supply -- permanently, in the long run -- at prices lower than current prices, then there is producer surplus. This most certainly is the case in the world oil market.

I emphasize this because the so-called "zero profit theorem" (ZPT), depending exactly on how it is stated, can incorrectly imply or state that in the long-run market equilibrium, producer surplus necessarily is zero. Generally, the ZPT means to tell us that "upward" pressure from factor prices and "downward" pressure from product prices tend to squeeze "profit," defined as revenue in excess of economic cost, towards zero. As this sort of general statement of economic forces at work, the ZPT is valid. However, the ZPT also has been formulated to explicitly deny the possibility of producers surplus in the long-run equilibrium. Consider the following excerpt from Hirshliefer (1976): "The accounting profit attributed to the firm controlling a rich ore body may indeed be high. But in principle, that firm could cease its operation and lease or sell the ore body to another. It should therefore charge itself, as an *economic cost* of its mining operations, the highest bid an outsider would make for the right to exploit its ore" (p. 263, emphasis in original). Hirshliefer (1976) is arguing that one should count as an economic cost whatever one would get as a result of selling off title to low-cost resources or production factors, such as land or patents. In his formulation of the ZPT, all apparent true rent or surplus actually is counted as an economic cost, on the grounds that the title to the underlying low-cost resources has value itself. But this, simply, is to confuse value with cost. The title to the Saudi's oil is valuable, but in itself involves no resource cost. Indeed -- and here is the rub -- the title is valuable *because* the oil is low cost -- because one will get revenues in excess of one's true economic cost. To turn around and refer to the revenues in excess of cost as a cost themselves is to undermine the original, solid definition of resource cost. If a cost embodies matter or energy, materials or labor, then there is indeed such a thing as producer surplus, or rent, in the long-run equilibrium, and the ZPT as presented by Hirshliefer is confused.

Thus, the producer surplus is not part of the social cost; rather, it is part of net benefits. (Put another way, it is a transfer of wealth from consumers to producers.) An estimate of price times quantity will misestimate social cost by the amount of the producer surplus.

It is clear, then, that price-times-quantity is conceptually different from social cost, and that in principle one ought not to mix the two or use one as a surrogate for the other. However, it is practically impossible to avoid this, and difficult to evaluate the extent of the error introduced. The main problem is that the relevant supply curves often are not known. If a supply curve is relatively steep, and price does equal marginal cost, then there will be a relatively large producer surplus, and hence a large error. Conversely, if a supply curve is relatively flat, then average cost will be close to marginal cost, and price-times-quantity will be close to total social cost. But it also can happen that, for a short while, price is below long-run marginal cost, in which case there is a region of negative producer surplus. (In this case, price-times-quantity might actually be less than total social cost; the industry operates at a loss. Some automobile companies have had major losses in recent years.) Moreover, for a regulated industry, price might be set at average cost rather than marginal cost. In this case, a price-times-quantity estimate would be an average-cost-times-quantity estimate and hence a social-cost estimate.

There is a major further complication. It is in fact practically impossible to make an estimate of cost that is free of producer surplus. Any estimate of cost will at some level involve price-times-quantity, and price times quantity includes producer surplus. For example, suppose that instead of multiplying the quantity of gasoline consumed in the U. S. by the average (quantity-weighted) retail price, we actually try to estimate the average cost of gasoline, and multiply this by the quantity consumed. We estimate the cost of crude oil to the refiners, the cost of refining, and the cost of gasoline marketing and retailing. But what is the cost of crude oil to refiners? Just the price paid times the quantity bought. And in the case of crude oil, the producer surplus can be substantial, because for many producers, especially those in the Middle East, the cost of production is much less than the prevailing world price of oil. And this difficulty does not disappear if we try to estimate the total cost of producing crude oil, because the components of *that* cost estimate include prices of materials and services.

For these reasons, we use whatever cost or price information is available, and make essentially ad-hoc estimates of the producer surplus component of the price-times-quantity estimate (Chapter 3)[11]. We do this only for private-sector motor-vehicle goods and services (column 1); for all other goods and services, we simply ignore the

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Tietenberg (1996, p. 45) puts it succinctly: "Most natural resource industries ..give rise to rent and, therefore, producer's surplus is not eliminated by competition, even with free entry."

[11]Why not use price times quantity information exclusively, and compare all options by this measure? First, for the unpriced items (e.g. the classical externalities), there are no prices; one would have to estimate marginal cost and assume that price would equal marginal cost. Second, and more important, price times quantity, as such, is not a useful measure, because it comprises benefits (producer surplus) and costs both, in unknown proportions. Two options with the same demand curve and the same marginal cost -- and hence the same price-times-quantity -- may or may not have the same total cost and net benefits. If one option involves a larger producer surplus, it will have lower total cost and greater net benefit. One option will have a larger consumer surplus if its infra-marginal supplies are less expensive than those of the other option. This possibility is not merely theoretical: it probably characterizes energy supplies, which can have radically different supply curves.

issue. However, we do *not* deduct producer surplus that accrues to foreign countries, because *that* surplus is not a benefit to the U.S. In other words, the portion of price-times-quantity payments by U.S. consumers that constitutes the producer surplus of foreigners is a net cost to the U.S., not balanced by an internal benefit, and so should be counted as a cost[12]. We have crudely estimated the foreign producer surplus on U.S. purchases.

2.3 THE CLASSIFICATION AND INTERPRETATION OF PERSONAL NONMARKET COSTS

2.3.1 An short elaboration of the classification scheme Report #1

As indicated in Report #1 and Table 1-1, some unpriced costs are not externalities. For example, the pain suffered by an individual as a result of an accident that he causes is not an externality, because the individual that causes the accident bears the consequences, but it certainly is an unpriced nonmarket cost, assuming that the individual is willing to pay to be rid of the pain. A society with less such pain is better off than one with more, all else equal, regardless of who causes and bears the pain. Hence, such "costs" must be included in the social cost, whether or not they are externalities. Put another way, some unpriced costs are actually private [nonmarket] costs. Thus, while total social cost is equal to private plus external (non-private) costs, or efficiently priced plus inefficiently priced plus unpriced costs, not all private costs are priced, and not all unpriced costs are external costs.

2.3.2 More on prescriptions

The concern that one might have about unpriced private costs (personal nonmarket costs) is that the person who bears them might not be aware of them fully. If he is not fully aware of them -- that is, if he underestimates the cost to himself -- then he will over-consume the good or service associated with the cost. The prescription, obviously, is to make sure that economic agents are fully informed about personal nonmarket costs. This means, for example, that a driver should know his risk of injuring himself on the road.

Note that this is different than the concern about externalities (which are costs inflicted by A on B but not accounted for by A). Externalities are due ultimately to a lack of property rights, and must be addressed by changing prices.

In principle, to introduce overlooked or underestimated personal nonmarket costs into the calculus of individual decision makers, one need only point out the costs to the relevant parties: given that the party responsible for the cost bears it, pointing out the cost should be sufficient to induce the decision maker to account for it. In this case not only is there no *problem* with prices, prices actually never even enter the picture, because there is no transaction, no exchange between parties (the individual "consumes" his own "production"). Externalities, on the other hand, typically demand

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[12]Well, not quite. The oil exporters will use some of their U.S. proceeds to buy U.S. products. Part of their payments back to the U.S. will constitute U.S. producer surplus, which is a real benefit to the U.S. This producer-surplus benefit to U.S. producers (which results from oil exporters spending their U.S. revenues in the U.S.) should in principle be netted out against the pecuniary cost of paying foreign countries for oil. We have not done so here.

some sort of pricing remedy, such as an externality tax, to make the responsible party face the marginal social cost of her actions on others. This prescriptive difference is important in principle because it is vastly simpler and less controversial to provide information than to fix prices.

In practice, however, overlooked internal costs probably are not terribly relevant. We can think of two such costs, theoretically: i) overlooked or underestimated risks to oneself of an accident of one's own causing; and ii) overlooked effects on oneself of pollution from one's own car. It is likely that many people do underestimate the likelihood of their causing an accident, but this already is well known and to some extent addressed by information campaigns (for example, against drunk driving). Moreover, when considering the risk of an accident while driving, individuals may not always distinguish between risks from other others and risks from themselves. Hence, there is no practical reason to distinguish overlooked internal accident costs. In the case of pollution, the irrelevance again is double: first, the cost to oneself of one's emissions is a small fraction of the total social cost of one's emissions; second, it usually is not possible or of practical significance to distinguish between one's own emissions and the emissions of others. For these reasons, we have not made a separate category for overlooked or underestimated personal nonmarket costs (as opposed to fully accounted for personal nonmarket costs) in Table 1-1 of Report #1.

There is another way to view the difference between externalities and overlooked personal nonmarket costs. This view starts with the total risk or cost that a motorist faces. The first requirement of efficiency is that the motorist be informed of the total risk and effect, so that she may fully them incorporate into her marginal-value equals marginal-cost decision making and arrive at her optimum consumption. This requirement that she be informed of the cost does not distinguish according to cause of the cost; it is sufficient that she be aware of the *total* cost she faces, regardless of the source. Moreover, she should not receive any compensation from perpetrators of costs inflicted on her (Cropper and Oates, 1992), although she certainly may buy insurance to protect herself. However, the perpetrators should face the marginal social cost of the damages that they impose on others; that is, externalities should be taxed. Thus, we find that, on the cost-bearing side, information and rational decision making is sufficient; on the cost-causing side, an externality tax is required if the cost is inflicted on others accounted for by the perpetrator. In the case of accidents, a motorist should be charged (either directly or via insurance) for the expected marginal cost of accidents that he imposes on others, but he should consider in his mode choice the total cost to himself, due both to himself and others, of accidents. And, again, victims should not be directly compensated by perpetrators; rather, they should be left to purchase insurance against risks as they see fit (see the discussion of efficient treatment of externalities, in Report #9).

In some sense, then, these non-market costs must be accounted for in two ways (but not double counted): the perpetrator of an externality must be charged for the cost he imposes, and the victim must face and account for the cost he bears. Put another way, in the absence of true property rights, externalities should be priced asymmetrically: there should be a cost to the perpetrator, but no "revenue" (compensation) to the victim.

2.3.3 "Rational" driving decisions, within the economic framework

We have said that in order to have an efficient level of nonmarket personal costs, the individuals who make the relevant decisions, such as whether and when to drive, must be informed and rational. It is interesting to consider further exactly what we might mean by "rational" decision making by drivers. For example, what can we say about the person who falls asleep at the wheel and runs into a tree, or the drunk who drives his car into a ditch? Are these instances of irrational behavior, and if so, what do we do about them? In the case of falling asleep at the wheel, what matters is whether the driver, before undertaking or continuing a particular trip at a particular time under particular conditions, correctly assesses the probability and consequences of falling asleep at the wheel -- not whether, in the instant of falling asleep, the driver makes a decision the "rationality" of which can be assessed. That is, economic inefficiency results from incorrect risk-assessments made prior to falling asleep, not from the act of falling asleep, which in the event is not a "decision" mindful of logic and information. In the end, falling asleep is beyond one's control, and a given probability, no different from the probability, also given, that a tire will explode and send the car into a tree. In a world of perfect information and logic, people still will fall asleep at the wheel and tires still will explode, just as in a world of perfect prices there still will be some pollution. The *economically* optimal amount of sleeping behind the wheel is not zero. (Note the emphasis on *economically.*)

The case of drunken driving might seem trickier, because one can imagine that a drunk still does make decisions, albeit with impaired judgment. It is most sensible, however, to view drunkeness as an incorrigible impairment of judgment, and demand rationality not from the drunk but from the sober man. That is, for efficient use of transportation, we should require not that the drunk be informed and rational as he fiddles with his keys ready to start his car, but rather that before becoming drunk he makes *rational plans*. We will have an efficient outcome if drivers are informed and sensible about their options, before they are drunk. And we can expect, again, that the optimal amount of drunk driving will not be zero, although given the terribly high costs of drunk driving, and the relatively low cost of alternatives, we can presume that the optimal amount will be very much less than the present amount.

2.3.4 Drunk driving, motor-vehicle-related crime, and the like: an alternative classification

The foregoing does not imply that we should or routinely do analyze drunk driving, and in general motor-vehicle related crime, as potentially rational economic behavior. To the contrary, drunk driving is illegal and repugnant. I have adhered strictly to the economic concept of behavior and "optimality" because that, after all, is my aim: to classify costs in a framework of economically efficient resource use, based on the classical economic model of "optimal" behavior. The model is amoral, or more precisely takes expressed individual preferences as given, and not subject to amendment within the model on moral grounds. However, in cases such as this (drunk driving), the price of conceptual consistency is an unrealistic and perhaps offensive insensibility. The market generally is constrained by our views of right and wrong, not vice versa. If we feel that drunk driving is immoral, and ought to be regulated accordingly, then in practice we have removed it from the economic sphere, and have rendered irrelevant at best, and insidious at worst, analyses of the economically optimal amount of drunk driving. On this view, it is better to classify costs associated with drunk driving, and with other immoral and illegal acts (such as motor-vehicle theft), outside of the framework of economic efficiency -- as, simply, costs of immoral or illegal behavior. Then, the prescriptions are moral suasion and enforcement of the law, not perfect information and rational decision making.

Note, though, that even if one analyzes and classifies drunk driving and motor-vehicle related crime in general from the perspective of right and wrong rather than from the perspective of economic efficiency, it remains true that the accident costs of drunk driving, and at least some of the pain and suffering costs of motor-vehicle crime in general, are costs of motor-vehicle use, and so must be *counted* as costs in an analysis such as mine. All else equal, if at present there *are* drunk driving accidents, then, in general, the less that people drive, the fewer drunken driving accidents there will be. Similarly, the less people use cars and drive, the less crime there will be in general, unless there are perfect substitutes for *every* motor-vehicle-related crime (which is unlikely). The question is not whether to count the costs; the question is how to classify them and what to do about them. In a classification scheme built upon principles of economic efficiency, drunken driving costs are personal non-market costs or externalities, and some of the costs of some motor-vehicle related crimes are externalities. However, even though such costs must be *counted*, they do not have to be *classified* within an economic framework: in general, it obviously is possible, and probably is desirable, to classify them not as externalities or personal non-market costs, but rather as consequences of illegal and immoral behavior.

In the end, we come down to this: a cost classification more broadly appealing and useful than mine might have than just categories pertaining to economic efficiency; it might include, at least, a non-economic category, "costs of immoral or illegal behavior," the prescription for which would not be any pricing or information scheme, but moral suasion and enforcement of the law. Into this category one might place such things as drunken driving motor-vehicle-related crimes. For the sake of simplicity and conceptual integrity, I have not added such a category, although I in Table 1-1, I have marked with an asterisk the costs that might go into such a category.

2.4 TO WHAT EXTENT ARE GOVERNMENT SERVICES RELATED TO MOTOR-VEHICLE USE PUBLIC GOODS?

To what extent are government services (police protection, fire protection, judicial and legal services) public goods? This question is important because to the extent that any of the services are public goods, they are not a cost of motor-vehicle use or anything else, and should not be included in the social-cost analysis. The public-good portion should be deducted from the total cost of the services, and the *remainder* allocated to the various "uses," such as motor-vehicle use, according to plausible relationships between marginal cost and use.

For example, some aspects of police deterrence work, as opposed to investigative work, *might* be quasi-public goods, in the sense that, in some cases, some of the resources devoted to patrolling might be relatively invariant with the amount of crime. Similarly, but more plausibly, some portion of fire protection *capacity* will be a public good, in so far as the investment in fire-fighting capital and personnel is scaled to handle particularly demanding fires. In either case, the cost of any such public-good like services by definition is not an opportunity cost of any specific activity or "use," such as motor-vehicle use, and hence cannot be assigned or allocated to any particular use on the basis of economic opportunity cost[13].

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[13]An obvious reminder: don't confuse public-good costs with fixed costs. The building that houses the highway patrol is a fixed cost in the short run, but in the long-run is a marginal cost of motor-vehicle use.

In Report #7 in this social cost series (see the list at the beginning of this report), we discuss this question further, and present ad-hoc estimates of what the public-good component of police and fire-protection costs might be. We believe that there is very minor public-good component to police services, and a larger but still probably moderate public-goods component to fire protection services.

However, we assume that there is no public-good component of the cost of the judicial, legal, or correctional system (jails, prisons, probation, and parole). In these systems, the total amount of resources is a function in the long run of the number of cases. Moreover, resources always are devoted to individual cases, such as motor-vehicle crimes. For example, the judge presiding over the motor-vehicle theft case is not available for another case, and the number of judges, and hence the size of courthouses and administrative staff, in the long run is roughly proportional to the total number of cases. Similarly, the cell housing the motor-vehicle thief is not available for other criminals, and the number of cells, and hence the number of guards and administrators, in the long run is proportional to the number of inmates. The provision and cost of these services is proportional, almost down to the last dollar, to the last individual crime.

2.4.2 General defense.

There might be some question as to whether general defense of the realm, which normally is taken to be close to a pure public good, really is a such a pure public good. For example, one might argue that defense resources are proportional to GNP, so that to the extent that motor-vehicles contribute to GNP, defense expenditures are cost of motor-vehicle use. This is an interesting but I believe ultimately flawed argument. First, given that defense is defense against threats, the argument requires that the threats themselves be proportional to GNP. But this typically is not the case: people fight over politics, religion, ethnicity and culture, raw resource endowment (as opposed to GNP), and strategic location -- but almost never over high versus low GNP. Some Islamic countries dislike the U.S. because of its Judeo-Christian culture and politics, not because it has a high GNP; these countries would hate the U.S. as intensely at half the GNP.

Second, in my analysis it does not matter any whether defense expenditures are or should be proportional to GNP, because in effect I am taking benefits for granted: I assume that the baseline, or counterfactual, is the same level of services but at zero cost. Put another (probably confusing) way, even if general defense expenditures really were not a public good, and were a marginal cost of something, they would be a cost of the *benefits* provided by motor-vehicle use.

In sum, because in my analysis there is no explicit or implicit change in services or GNP, there is no possibility of a change in defense expenditures. No portion of *general* defense costs sensibly can be assigned to motor-vehicle use.

On the other hand, any patrol that is largely independent of the amount of persons or activities, in the long run as well as the short run, is a public good.

2.5 THE SOCIAL DISCOUNT RATE

In most projects, some costs and benefits accrue now, and some accrue later. But we do simply add current and future costs and benefits at their face (nominal) values; first, we must determine the worth *today* of the face value of the future costs and benefits. What, for example, is the worth today of a life lost 20 years from now, on account of air pollution today? To answer this question, we apply the social discount rate -- the rate of tradeoff between now and later.

We address three separate questions as regards the discount rate: 1). Should the social rate of discount be the same in all applications? 2). Should one use a real (inflation-free) rate, or a nominal rate? 3). What exactly should the rate[s] be? We then consider an application of the discount rate in cost or cost-benefit analysis.

2.5.1 Should the social rate of discount be the same in all applications?

It is not obvious that the social discount rate should be the same in all applications. As discussed below, society should discount financial returns differently, depending on the source of funding. Furthermore, society may discount future financial costs (e.g., highway costs) differently than future mortality risks from, say, carcinogens (Moore and Viscusi, 1990a: S-52). We consider the literature that has developed on choosing the social rate of discount for financial costs and benefits, and then briefly consider the evidence for whether there are differences between society's discount rate for financial costs and health risks.

Deriving the social rate of discount for financial costs (Arrow, 1965; Baumol, 1979; Lind et al., 1982; Cline, 1992)

Fundamentally, there are three distinct reasons that we might prefer having a dollar today to having a dollar a year from now:

i) we might die in the intervening year;

ii) we might be wealthier a year from now, and hence find the marginal dollar less useful then rather than now;

iii) we can invest the dollar today and have more than a dollar available a year from now.

We can say that: i) expresses the "pure" social rate of time preference in consumption; ii) expresses the effect of increasing wealth and diminishing marginal utility of consumption; and iii) represents the rate of return on investment in private capital. The first two together may be said to constitute the social rate of time preference in consumption. In markets with no risk, no distorting taxes, no externalities, no barriers to market entry and exit, perfect information, no transaction costs, no restrictions on capital formation, and so on, the social rate of time preference will equal the rate of return on investment in private capital, and this will be our uniform social rate of discount. Of course, none of these prerequisites obtain, and as a result we observe (or infer) a wide variety of discount rates in the economy. The challenge, then, is to derive the social discount rate from the plethora of observed interest rates in the economy -- or, in the case of goods without easily observed markets, such as health risks, to infer the discount rate from existing markets or surveys of individual preferences.

One general rule, established over the past 30 years at least (e.g., Arrow, 1965; Baumol, 1979; Lind et al., 1982; Cline, 1992) is that the social rate of discount for any public project must reflect the [different] rates in each of the sectors of the economy from which the resources are taken. Thus, by this method, the effective discount rate will be different for different projects, because the source and hence opportunity cost of the resources will vary from project to project. (Exactly what we mean by different "sectors" will become clear shortly.)

As mentioned above, observed rates vary because of differences in risk, differences in taxes, differences in transaction costs, and other factors. Of these, the most important, and the most often analyzed, are differences in taxes and differences in risk (e.g., Baumol, 1979). On the basis of these two factors, we distinguish returns to personal consumption from returns to private corporate capital.

How taxes affect the rate of return.

The corporate income tax on earnings forces the before-tax rate of return to private capital to be higher than the rate on untaxed returns, such as from riskless government bonds. The reason is clear enough: the corporations must compete on the basis of the actual return -- the *after-tax* return -- to *investors*. If the after-tax rate of return on investment in a corporation is lower than the rate provided by, say, government bonds, nobody will invest in the corporation. The corporation must earn a return large enough *before* taxes so that the *after*-tax return paid to investors is competitive. Formally, "for production whose returns are taxed at a rate such that the fraction 1/k of the returns *remains* after taxes, the opportunity cost rate of the resources withdrawn from that sector will be k*i percent" (Baumol, 1979, p. 561; I have substituted "i" for his "r"), where i is the rate of return on "production" not subject to taxation (e.g., the rate on riskless government bonds).

Note that, although the relevant opportunity cost to private *investors* is the after-tax rate of return, the relevant *social* opportunity cost is the before-tax rate of return. What initially is available to society is the return before taxes; a portion of this before-tax return goes as taxes the government, and a portion goes as dividends to investors. The payment of taxes is a disposition of the real total returns, just as is the payments of dividends. Again, Baumol (1979) puts it well:

> ...the presence of special taxes on the output of this sector means that resources invested in it must produce goods and services valued at a level sufficiently high to yield a [k*i] percent return. The corporation can then engage only in the production of consumers' or producers' goods whose purchasers value them sufficiently to pay a price that yields a [k*i] percent return on corporate investment. A withdrawal of resources from the corporation, then, will cause a reduction in output whose opportunity cost in terms of consumer valuation is given by that figure: [k*i] percent. (p. 559; brackets added, "i" substituted for "r")

Risk and the discount rate

Risk also can cause differences in rates of returns: risky investments generally will yield a higher rate of return than will safe investments. Regarding risk, the important point is that the opportunity cost of removing funds from the private sector is the foregone rate of return with the risk "premium" included. The reason is the same as the reason that the before-tax rate of return, not the after-tax rate of return, is the opportunity cost of not investing in private capital: the risk, like the tax, forces the corporation to invest only in opportunities with a relatively high return. The social opportunity cost of not investing (of using the funds for a public project) is thus this relatively high real return.

Return to personal consumption versus returns to private corporate capital

Because returns to private corporate capital are subject to a corporate income tax, and because investments in private corporate capital generally are riskier than investments in, say, government bonds, we find that the before-tax, risk-inclusive rate-of-return to private capital is quite a bit higher than the social-rate of time preference as revealed by interest rates on government bonds and the like. For this reason, it will be useful to distinguish between resources diverted to a public project from personal consumption, and resources diverted from investment in private corporate capital. The opportunity cost of the resources diverted from consumption will be the return to consumption, given by the social rate of time preference. The opportunity cost of the resources diverted from private corporate capital will be the before-tax, risk-inclusive rate of return to investment in private corporate capital. I will consider these two sources in my estimation of a weighted-average discount rate to apply to public investment in infrastructure (Section 2.5.4, below).

Discounting future financial costs versus discounting future health effects

Moore and Viscusi (1990) note that, due to imperfect markets, society's rate of time preference for health risks may differ from the real rate of return on financial resources. Similarly, society may discount differently possible declines in biological diversity due to global warming or other goods for which there are poorly defined markets.

However, given that we may estimate the dollar value that society places on health effects, one reasonably might ask why we should not simply discount these future monetized health effects using the same social rate of discount that we use for the "financial" items such as highways. Cropper and Portney (1990) raise this issue and conclude, using a life-cycle consumption model, that a separate discount rate is unnecessary. Similarly, Fuchs and Zeckhauser (1987) argue that the same discount rate should be used whether we are looking at health or highways. Nevertheless, we agree with Viscusi and Moore (1989) that this is an open question, and that one should test empirically whether capital markets accurately reflect the tradeoffs that society makes regarding health risks. In Section 2.5.3, we present some of the available empirical evidence. As summarized there, a number of recent studies using surveys (Cropper et al., 1994; Horowitz and Carson, 1990) and wage data (Moore and Viscusi, 1990a, 1990b; Viscusi and Moore, 1989) have looked at how people discount health risks (i.e., mortality risks), and found discount rates ranging from 1% to 17%

2.5.2 A real or a nominal rate?

If a cost or cost-benefit analysis is to be done with nominal prices, such that current prices are inflated to obtain future prices, then of course the corresponding discount rate should be the nominal rate, equal to the real interest rate + inflation rate + (real interest rate · inflation rate). Alternatively, if the analysis is to be conducted entirely in terms of current prices, with no inflation, then one should use the real (inflation-free) social discount rate. It generally is easier to use current prices and a real discount rate, and I do so here.

There is, however, a subtle difficulty with using a real discount rate: namely, that nominal rates, or more precisely amortized costs based on nominal rates, are embedded in current prices and costs. Suppose, for example, that we wish to estimate the annualized cost of a battery-powered electric vehicle. This annualized cost is equal to annual operating and maintenance costs, plus the amortized initial cost. Suppose that we have the following data:

nominal discount rate = 10%
expected inflation rate = 3%
current-dollar operating and maintenance costs = $200/year
the initial cost of the vehicle, in current dollars = $20,000
life of vehicle = 12 years

We can calculate that the real discount rate is 6.8%, and that the amortized initial vehicle cost, using the real discount rate, is $2,490/year. The total annual cost is then $2490 + 200 = $2,690/year. But let us look more closely at the current-dollar initial cost of $20,000. Suppose that this figure was given to us by a prospective manufacturer of battery-powered electric vehicles, who tells us that he estimated the initial cost per vehicle as:

Lv + Mv + Bv + Ca/Va,

where:
Lv = marginal labor cost required to build a vehicle (say, $3,000),
Mv = marginal materials (excluding battery) cost of each vehicle (say, $3,000),
Bv = cost of batteries required for each vehicle[14] (say, $4,000),
Ca = amortized capital and overhead cost of the vehicle-production plant,
Va = annual output of the plant (by subtraction, Ca/Va = $10,000).

We now see the potential inconsistency: the vehicle manufacturer most likely used a nominal rate to amortize his capital and overhead cost, to obtain Ca. Thus, in order to have an internally consistent estimate, done entirely in terms of real rates, we will have to redo the calculation of Ca using the real rate of interest. For the sample data given above (and assuming a production-plant life of 30 years), the value of Ca/Va at a real rate will be $7,440 instead of $10,000, the initial cost of the vehicle now will be $17,440, the amortized initial vehicle cost will be $2,170, and the total annual cost will be $2,370 -- 12% lower.

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[14] Batteries are itemized separately because they are such a large cost.

But we still are not done. What about the $4,000 battery cost -- given to the vehicle manufacturer, presumably, by a battery manufacturer? We should have the same concern: namely, that the battery manufacturer probably used a nominal rate in order to amortize his investment to arrive at a per-battery wholesale cost. We will have to redo that calculation, too.

And so it will go. If we use a real discount rate to amortize a total initial investment, we should in principle make sure that every component or sub-cost of that total investment is itself estimated on the basis of a real and not a nominal rate. That, anyway, is the principle. In practice, it will be tedious to do this. In this analysis, we use the real rate to amortize the "first-order investment costs" (parking facilities, highways, garages -- analytically comparable to the vehicle in the example above), and assume that, unlike in the vehicle example just given, any second-order or embedded amortized investment costs are relatively minor, and can be ignored.

2.5.3 So what should the rates be?

The theoretical and empirical literature on the social rate of discount is enormous. Here, we can offer only a sampling of the values presented in the literature, for a wide variety of applications, and hope that the sample is consistent with the "true" range of values in the complete literature. We distinguish generally between discounting financial costs, and discounting health effects.

Discounting future financial costs:

- In the 1980s, the real Prime lending rate by banks was about 6%, the real mortgage rate for homes was about 7%, and the real effective rate on Federal Funds and the rate on 1-year Treasury Bills was about 4%[15] (Bureau of the Census, *Statistical Abstract of the United States*, 1992). The real rate of interest on new-car loans was about 8 % (*Annual Statistical Digest*, 1983, 1986, 1989; *Federal Reserve Bulletin*, 1992). However, Cline (1992) cites, and Blincoe (1996) and Blincoe and Faigin (1992) present, data that indicate that the long-term real rates are lower than were the real rates in the 1980s.

- From 1989 to 1991 the nominal prime rate of interest charged by banks on short-term business loans ranged from 8.46 to 10.47%; the nominal rate of return on 5-year constant-maturity Treasury Bills ranged from 7.37 to 8.50%; the nominal rate on AAA corporate bonds ranged from 8.77 to 9.32%; and the dividend-price ratio on preferred stocks ranged from 8.17 to 9.05% (*Federal Reserve Bulletin*, 1992).

- In their estimates of the medical costs of cancer, Brown (1990) and Rice et al. (1985) used real discount rates between 4% and 6%.

- Cline (1992) argues that theory and data indicate that the social rate of time preference is around 1.5%, and that the rate of return on private capital is around 8%. Although Cline applies this rate to the future

[15] The after-tax rate of return, which is relevant to private consumption, would be lower.

costs of global warming, he states that the underlying method is "squarely in the mainstream of recent cost-benefit analysis" (p. 267), and that he has not made any adjustments for any arguably "special" characteristics of global warming, such as its potential to result in big problems hundreds of years from now.

- In Report #11 of this social cost series (see the list at the beginning of this report), McCubbin and Delucchi measure growth in wealth per capita in several ways, and find rates of 0.5% to 2.0% per year.

- The Office of Management and Budget suggests a real discount rate of 7%.

- Miller et al. (1985) suggest a rate of 4-5% for evaluating highway safety projects, with sensitivity checks of 3% and 7%.

- Randall (1981) suggests that public investment should be evaluated using a social discount rate that reflects the marginal efficiency of investment, which he estimates to be 6% real.

- In their example calculations of parking costs, Weant and Levinson (1990) use a nominal rate of 9%, which corresponds to a real rate of about 5%. Shoup (1995) assumes a real rate of 4% to amortize the cost of parking facilities.

Discounting future health effects:

- Horowitz and Carson (1990) asked students to trade off current deaths for future deaths, and on the basis of their choices found the implicit discount rate ranging between 4.5% and 12.8%.

- Cropper et al. (1994) surveyed adults in Washington, D. C. about the preferences regarding saving lives now versus in the future. The responses indicated that the implicit discount rate was 16.8% for a time horizon of five years, 7.4% for a time horizon of 25 years, and 4.8% for a time horizon of 50 years.

- Several papers attempt to look at workers' real rate of time preference with respect to health risk, using wage data and estimated job risks. Moore and Viscusi (1990a; 1990b) and Viscusi and Moore (1989) use a variety of models and estimate that the tradeoff between lower fatality risk and higher wages suggests an implicit discount rate ranging from 1% to 14%.

- Miller et al. (1991) use real discount rates of 2.5% and 4.0% to value future costs of injuries in automobile accidents. In support of this choice, they cite the study by Horowitz and Carson (1990), and Moore and Viscusi (1990b). Blincoe and Faigin (1992) and Blincoe (1996) review long-term rates of return on stocks and 3-month Treasury bills, and conclude that a real, after-tax rate of return of 4% is appropriate for injuries from automobile accidents.

We are in no position to make theoretical or empirical contributions to the controversy regarding the appropriate social rate of discount. Instead, we pick lower and upper bounds that appear to span the range of reasonable opinion.

Conclusion: Discounting injuries and death from automobile accidents (Reports 4 and 9) and automobile air pollution (Report #11)

The estimates cited above suggest that the appropriate rate at which to discount future injuries and deaths lies between 1% and 17%. The upper end is less common and seems implausible to us. We choose a range of 2% to 8%. The lower end of this range probably still is more reasonable. If one believes that the appropriate discount rate on health effects is the social rate of time preference, then one should use a discount rate of 2% or even lower. Cline (1992) argues that future health effects should be discounted at only 1.5%.

Conclusion: Discounting the future effects of global warming (Report #9)

As our estimate of the costs of global warming relies heavily on Cline's (1992) analysis, we in effect are accepting Cline's rates, which as mentioned above yield an equivalent overall discount rate of on the order of 2%.

Conclusion: Amortizing private investment in motor vehicles (Report #5)

As mentioned above, in the 1980s the real rate of interest on new car loans was about 8%/year, and in earlier decades it probably was less. Although it might seem appropriate to use the long-term loan rate to annualize the cost of motor vehicles, the opportunity cost of the investment in motor vehicles is not necessarily the loan interest rate actually paid. Rather, it is the returns foregone from the alternative use of the resources, plus the transaction cost of taking out the loan. If the alternative use of the resources is investment in private corporate capital, then the foregone rate of return is that yielded by private corporate capital, which according to the above is on the order of 8%. If the alternative is pure consumption, then the foregone will rate will be much lower.

The opportunity cost of the investment, and hence the appropriate interest rate, will be different for individuals buying vehicles for personal use than for business buying vehicles for business use. The individual buying for personal use probably gives up more consumption than direct investment in private corporate capital, whereas for businesses it probably is the other way around.

With these considerations, and allowing further for the transaction cost of taking out loans, I assume a range of 4% to 7% for personal-use vehicles (light-duty autos and light-duty trucks), and 5% to 9% for commercial-use vehicles (heavy-duty vehicles).

Conclusion: Amortizing private investment in homes (Report #14) and residential garages (Report #6)

As mentioned above, in the 1980s the real mortgage rate was about 7%/year, and in earlier decades it probably was less. However, the opportunity cost of the investment in homes and residential garages is not necessarily the mortgage rate actually paid, but rather is the returns foregone from the alternative use of the resources (plus the transaction cost of taking out the loan). If the alternative use of the resources is investment in private corporate capital, then the foregone rate of return is that yielded by private corporate capital, which according to the above is on the order of 8%. If the alternative is pure consumption, then the foregone will rate will be much lower.

Investment in residential garages probably displaces consumption more than it does direct investment in private corporate capital. With this assumption, and allowing for the transaction cost of taking out loans, we assume a range of 4% to 7%.

Conclusion: Amortizing private investment in roads and offstreet nonresidential parking spaces (Report #6)

The opportunity cost of private investment in local roads and offstreet parking spaces generally will be the rate of return on private corporate capital, which as discussed above appears to be on the order of 8%/year in real terms. We bracket this with a range of 6% to 10%.

Conclusion: Amortizing public investment in infrastructure (Report #7)

Highways are financed mainly from revenues from gasoline taxes and other user fees, and secondarily from general revenues. That is, virtually all highway construction costs are paid for directly by individuals. But from where in the economy, ultimately, are the resources withdrawn? As Baumol (1979) puts it, in principle we should determine "the catalog of the decrements in the outputs of the various portions of the private sector which would result from a governmental investment program" (p. 569).

Unfortunately, a formal analysis of the ultimate source of funds used to finance highway is beyond our scope here. Instead, we assume simply that the tax and fee monies that fund highways displace consumption rather than capital formation (investment) according to the economy-wide proportions of consumption and investment, which is about 4:1 (Cline, 1992). This suggests a weighed-average discount rate (d) on the order of 3 or 4%. We assume a range of 3% to 7%. We apply this range also to public investment in the Strategic Petroleum Reserve, and to capital used by police, fire, judicial, and correctional services.

2.5.4 Application of the discount rate in cost or cost-benefit analysis

As explained in Report #1 of this social-cost series, our analysis of the social-cost of motor-vehicle use actually is a *project* analysis -- an analysis of the cost of motor-vehicle use as if all motor-vehicle were a giant "project" to be evaluated by normal project-evaluation methods, and compared with alternative projects. There are two general ways to perform a cost or cost-benefit analysis of a project:

1). Calculate the present value of all future benefits or costs, and add this to the value of present (investment) costs or benefits.

2). Amortize present costs or benefits into an equivalent stream of constant periodic costs or benefits, (an annuity), and add this annuity to future constant periodic costs or benefits. As stated, this second method requires that actual periodic costs (e. g., operations and maintenance costs), be the same in every period (in constant dollars).

The discount rate of course is used either to calculate present value, or to amortize initial costs. In this cost analysis we adopt the second approach, in which initial costs are annualized (hence the title of Report #1). However in this section, we will explain both approaches, and the corresponding derivation of the discount rate, here.

1) *Calculate the present value of all future benefits or costs, and add this to the value of present (investment) costs or benefits*:

With this method, one first estimates the fraction of the total cost that displaces consumption rather than investment in private corporate capital. Then, one converts any displaced investment to "consumption equivalents" using the shadow price of investment (capital), which will be explained momentarily. One now has all the costs in terms of displaced consumption. This consumption-equivalent cost stream is discounted in the normal fashion to obtain net present value. The appropriate discount rate to apply to the consumption-equivalent cost stream to calculate the net present value is of course the social discount rate pertaining to consumption, or the social rate of [consumer] time preference. Cline (1992) elaborates the overall method:

> First, all effects should be divided into their investment and consumption components...Second, these respective consumption and investment effects over time should be converted to consumption-equivalents through the application of the shadow price of capital. Third the resulting consumption-equivalent magnitudes should be discounted at the estimated SRTP [social rate of time preference] (p. 266).

Formally, but in reverse of the preceding account:

$$V\cos t = I + PV\cos t$$

$$PV\cos t = \sum_{t=1}^{e} \frac{C_t *}{(1+i)^t}$$

or

$$V\cos t = \sum_{t=0}^{e} \frac{C_t *}{(1+i)^t}$$

where:

Vcost = the total value, in present consumption terms, of all of the costs of the project

PVcost = the net present value of the stream of costs of the project from the end of the first period to the end of the end (e) period.

I = the initial cost (investment; as indicated, this also could be included in the summation expression, as $C_{t=o}^*$, now starting at time zero, the beginning of the initial period)
t = the period in the life of the project
e = the life of the project (number of periods)
C_t^* = the cost of the project, taken at the end of the period t, in consumption-equivalents (consumption equivalence will be explained below)
i = the real social rate of time preference (discount rate pertaining to consumption; fraction per period)

Note that here, the weighting between resources withdrawn from consumption and resources withdrawn from private corporate capital is incorporated into C_t^*, the consumption-equivalent cost, which is explained next. Because costs in this method are expressed in consumption-equivalents, the correct discount rate to be used, *i*, is the social rate of time preference (the discount rate pertaining to personal consumption).

The consumption-equivalent cost of a project is equal to the cost to actual consumption (resources withdrawn from personal consumption) plus the consumption-equivalence of resources withdrawn from private corporate capital. The consumption-equivalent of a capital cost is equal to the capital cost multiplied by the shadow price of capital, which will be explained next. Formally:

$$C_t^* = Fc_t \times C_t + (1 - Fc_t) \times S_t \times C_t$$

where:
C_t^* = the cost of the project in period t, taken at the end of the period, in consumption-equivalents
Fc_t = the fraction of the cost in period t that displaces personal consumption rather than investment in private corporate capital
C_t = the nominal cost of the project in year t of the life of the project
S_t = the shadow price of capital investment in period t (present consumption-value of annuity from investment of X divided by the current consumption value of X)

The shadow price of capital tells us how many consumption dollars we must have now in order to equal the present value in consumption of the stream of returns from an investment of one dollar now. Technically, it is the ratio of the present consumption value of an annuity from an investment of X in period t to the current consumption value of X in period t. The present consumption value of the annuity from X is greater than the current consumption value of X because the investment is productive at r% per year, the rate of return to private corporate capital, but is discounted back at the lower i%, the social rate of time preference (as discussed above, taxes on corporate returns force r to exceed i). Formally:

$$S_t = \frac{\sum_{k=1}^{n} \frac{AX_t}{(1+i)^k}}{X_t}$$

$$AX_t = \frac{X_t \times r}{1-(1+r)^{-n}}$$

$$S_t = \frac{\sum_{k=1}^{n} \frac{r}{(1+i)^k}}{1-(1+r)^{-n}}$$

where:
S_t = the shadow price of capital investment in period t (as above)
k = the period in the life of investment X in period t (k = 0)
n = the life of investment of X (number of periods)
AX_t = annuity from the investment of X in period t (corresponding to k = 0), at a rate r over n years
i = the real social rate of time preference (discount rate pertaining to consumption; fraction per period)
r = the real rate of return on private capital or investment (discount rate pertaining to investment; fraction per period)
X_t = the amount for investment or consumption in period p (k = 0)

2) *Amortize present costs or benefits into an equivalent stream of constant periodic costs or benefits, (an annuity), and add this annuity to future constant periodic costs or benefits.*

Alternatively, if periodic [future] costs are constant, one simply can amortize the initial project cost, and add the resulting annuity to the periodic costs. In this case, one must divide the initial project cost into the portion that draws displaces personal consumption and the portion that displaces investment in private corporate capital, and amortize the former at the social rate of time preference and the latter at the rate of return on private corporate capital. Formally:

$$TP = P + AI$$

$$AI = \frac{Fc \times I \times r}{1-(1+r)^{-e}} + \frac{(1-Fc) \times I \times i}{1-(1+i)^{-e}}$$

where:

TP = the total periodic cost of the project
P = the constant periodic [future] costs of the project (e.g., operations and maintenance costs)
AI = the amortized initial cost of the project
I = the initial cost of the project

Fc = the fraction of the initial cost that displaces personal consumption rather than investment in private corporate capital

i, r, and e are as above.

The foregoing calculation of AI involves two separate amortizations, one of the capital-cost component at rate r, and the other of the consumption-cost component at rate i. To simplify this slightly, we can approximate AI with a single amortization of the entire cost I at a weighted-average rate d:

$$AI \approx AI^* = \frac{I \times d}{1-(1+d)^{-n}}$$

$$d = Fc \times i + (1 - Fc) \times r$$

where:

AI* = the amortized initial cost of the project based on the weighted-average discount rate, rather than the amortized weighted cost shares

d = the weighted average discount rate

For virtually any set of realistic parameter values, AI* is a very close to AI -- almost always within 10% (relatively), and often within 5%. It is slightly easier to program AI* than AI. Therefore, in this analysis we will calculate a weighted-average discount rate d, and use the approximation AI* for AI.

2.6 GENERAL TAXES: PERSONAL INCOME TAXES, CORPORATE INCOME TAXES, AND SALES TAXES

Corporate-income taxes paid by corporations in motor-vehicle and related businesses, and personal-income taxes paid by employees of motor-vehicle and related businesses, are part of the cost of motor vehicle goods and services, and hence part of the price that motor-vehicle users face[16]. In addition, the sales tax on motor-vehicles and related items is an explicit increment to the price that motor- vehicle users face. These taxes, of course, are not payments for private capital or labor used directly to make motor vehicles and related items; they are payments to the government. The question arises, then: how should these general taxes be treated? Can they be viewed as payments by motor-vehicle users for government-provided motor-vehicle-related services, such as police protection?

We believe that general taxes should be viewed as general payments to the government for a wide range of social services and "social overhead" -- part of the price of living and working and doing business in the U.S. Thus, we treat taxes as a mandatory charge for involuntary "consumption" of a wide range of public services or

[16]In addition, government expenditures on roads and motor-vehicle-related services are based on gross wage payments, not payments net of income taxes (Bureau of the Census, *Government Finances*, 1991). However, the wage and expenditure data do not include the value of payments in kinds for housing, subsistence, and other items.

activities[17]. Most of the general public services that these general taxes support are not related to motor-vehicle use, and hence most of the general-tax part of the price of motor-vehicle use cannot be viewed as a payment for government-provided motor-vehicle services specifically. However, public motor-vehicle services are *one* of many public services, and hence a portion of the general taxes in the price of motor-vehicle use does, in effect, go towards publicly provided motor-vehicle related services. We count only this portion as a payment by motor-vehicle users for government services in support of motor-vehicle use. We take up this issue in more detail in Report #17.

The obverse question is of whether or not energy producers and motor-vehicle manufacturers are receiving tax "subsidies" (or penalties), as a result of "preferential" or (unfavorable) tax treatment. We believe that there is no good conceptual ground for classifying a tax subsidy as an unpaid cost in an economic sense. The main problem is that there is no obvious relationship between the amount of taxes paid by any payer and the amount of resources, however broadly defined, consumed by (or even properly allocated to) that payer. This means that one cannot formally relate general taxes to real costs, and instead must make somewhat ad-hoc judgments about social obligations to pay for social services. But given this, it is just as likely that differential tax treatment reflects differential social obligations as it does unfair avoidance of social obligations. This is discussed further in Report #18.

2.7 THE PROBLEM OF THE "SECOND BEST"

In Report #1 of this series, I review the textbook conditions of economically efficient resource allocation. When all of these conditions hold, we have what often is called a "first-best" world. However, the real world rarely if ever is first-best, for rarely if ever do all of the necessary conditions obtain simultaneously in any given economic sector, if only because there always are imperfect taxes throughout the economy. At most, the real world is "second-best".

Given that generally we do not know precisely "where" the real world is in relation to the theoretical first best world, we might wonder how we can be sure that making piecemeal improvements -- eliminating a few sources of inefficiency at a time -- actually moves us closer to the theoretical first-best world. In general, we can't. This anyway is the somewhat discouraging conclusion of the "general theory of the second-best," originally developed and elaborated by Lipsey and Lancaster (1956-57) and Davis and Whinston (1965), and summarized here by Laffont (1990):

> (a) If a distortion exists in one sector (this is, there is some constraint that prevents the first-best optimal conditions from being satisfied in this sector), it is no longer generally desirable to apply the first-best optimality condition in other sectors...

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[17]Of course, the current income tax system may be a relatively inefficient way of charging for government services, and the government may be providing services relatively inefficiently. If in the future government provides services and collects revenue more efficiently, the total income tax burden -- and hence, to some extent, gross wage payments -- will decline (after-tax or net wages also should increase). The decline in gross wages will reduce expenditures for most goods and services, including those related directly or indirectly to motor-vehicle use (all else equal).

(b) If n distortions (where $n \geq 2$) exist, we cannot claim that the competitive equilibrium with n - 1 distortions is preferable to the competitive equilibrium with n distortions is preferable to the competitive equilibrium with n distortions...

(c) The problems of equity and efficiency can no longer be separated unless we use personalized lump-sum transfers as political economic instruments.

(d) The results obtained in second-best analysis may contradict the economist's intuition in the first-best analysis. (Laffont, 1990, page 167).

The broadest implication of the theory of the second best is that one really should do a full general-equilibrium analysis in order to determine the final efficiency effects of any piecemeal (partial) movements towards Pareto optimality. In the absence of such a general analysis, we cannot be sure that any measure to correct only one imperfection among many (e.g., a proposal to tax motor-vehicle emissions) actually will result in a Pareto improvement.

2.7 LAG BETWEEN CHANGE IN DEMAND AND CHANGE IN SUPPLY

A price equilibrates demand and supply; where there is no price, the link between supply and demand is broken, and a change in demand may affect supply only slowly, if at all. Consider the desire to protect oil supplies in the Persian Gulf. If these security services were provided for a large fee to oil companies by private firms, one can be sure that the oil companies would consider carefully how much security they needed, and when faced with less of a threat, immediately would buy much less protection. But in the real world the protection of oil supplies is bought by national military forces in the Persian Gulf, not negotiated in a market. The "appropriate" amount of protection is not determined by market supply and demand; rather, it is hashed out in the political arena, where bureaucratic inertia, vested political interests, a backlogged agenda, and genuine disagreement over facts and appropriate policies make it difficult to respond rapidly to dramatic changes in the condition of the world. So it was that several years after the collapse of communism and the Eastern Bloc, U. S. legislators and the executive branch had not yet appropriated for the citizenry the benefit of a diminished need for defense. The political process mediates between supply and demand much less effectively than prices do.

There are many other examples of this sort of lag. It occurs in virtually every case where budgets and expenditures are set by legislatures rather than by market prices: thus with police protection, fire protection, the court system -- with most government-funded activities related in some way to motor-vehicle use. It can take years to recognize and accept a change in conditions (e.g., reduced need for highway patrol, because of reduced motor-vehicle traffic), agree on the appropriate actions, and execute them. In extreme cases, pork-barrel politics and the budget-maximizing behavior of agencies can conspire to make government expenditures nearly independent of any "objective" measure of the need for services.

The upshot of this is that cost items that are subject to this lag cannot be understood to be normal short-run marginal costs of motor-vehicle use. Because of the political instead of price meditation between demand and supply, these lagged costs (resources) are not saved in the "short run" following a change in demand; rather they are not saved, or foregone, until years later. Thus, one would want to distinguish in this respect between the provision of police services, which probably significantly lags changes in demand (need), and the supply of gasoline, which more closely tracks demand[18].

2.8 THE USE OF 1990-91 DATA

2.8.1 The representativeness of 1990-1991 data.

We estimate social costs using data from 1990 and 1991. Obviously, the data were different for other years, and will be different in the future as a result of changes in population, demographics, income, economic activity, technology, preferences, funding mechanisms, legislation, weather, and a host of other factors. By the year 2010, enough of these factors will have changed enough to render many of the 1990-based cost estimates inapplicable. For example, environmental damages (per vehicle mile of travel) probably will decline considerably by the year 2010, because the 1990 amendments to the Clean Air Act are expected to greatly reduce emissions from motor vehicles. Net government expenditures (or subsidies) (per vehicle mile) also could change, especially if there is major new legislation affecting government expenditures or receipts relating to motor-vehicle use. Expenditures on highways might increase in order to meet prevent further deterioration of the nation's highways and bridges (FHWA, *1991 Status of the Nation's Highways and Bridges*, 1991).

2.8.2 The total annualized cost based on what is in place in 1990-1991, or on the rate of addition in 1990-1991?

We estimate the annualized cost of parking (Report #6), roads (Report #7), and vehicle (Report #5) capital on the basis of 1990-1991 data. There are two ways to interpret "annualized capital cost on the basis of 1990-1991 data:" 1) as the annualized replacement cost of the road, parking, and vehicle capital actually *in place* in 1990-1991; or 2) as the annualized cost of the total amount of capital that would be in place in at the 1990-1991 rate of addition (capital addition per year or household or vehicle or square foot, etc., multiplied by years of life, households, vehicles, square feet, etc.). In the first method, we would, in the case of parking for example, count up the number of parking spaces actually in existence in 1990-1991, and multiply this in-place total the average

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[18]Of course, in properly functioning markets as well there are lags between a change in demand and a change in the total amount of resources devoted to production. Firms can not vary *all* of their factors of production instantaneously to follow every minor change in demand, because many factors, such as buildings and large equipment can be "varied" (sold off, replaced, repurchased...) only at absurdly great transaction costs. There is, in fact a continuum of variability in production factors, from those that can be varied only at great transaction expense (e.g., buildings and land), to those that can be varied at virtually no transaction expense (e.g., electricity usage). The amount of resources saved in production as a result of a change in demand depends on the magnitude and expected duration of the change: the larger and more permanent the change, the more factors of production will be saved. At some point, fixed costs become variable. But it takes time for firms to be convinced that a change in demand is permanent enough to warrant varying all of its cost of production appropriately; hence there can be a lag between the change in demand and the savings in some costs of production. The point here, though, is that the substitution political for price mediation is an additional source of lag (and, more generally, of dissonance between demand and supply).

annualized cost per space, using 1990-1991 costs. In the second method, we might estimate the number of parking spaces actually *added* in 1990-1991, multiply by the lifetime of the parking spaces, and then multiply the resulting scaled total by the annualized cost per space.

The first method yields what we might call an “average” total, because it is based on the past average rate of addition of capital. The second method yields what we might call a “marginal” total, because it is based on the rate of addition of capital in 1990-1991. Which method is more useful depends on what one intends to do with the estimates, and what one believes about the future. For example, if one wishes to use the social-cost estimates to evaluate alternative investments, and if one believes that the near future will be more like recent past than the longer-term past, then the marginal total will be a more useful basis of estimation. On the other hand, for the purpose of estimating historical trends, the average total might be more useful.

In the case of roads (Report #7), we estimate the total capital cost two ways: by multiplying current capital expenditures by the life of the capital, and by multiplying miles of roadway in place by the current cost per mile. The two methods yield similar results. In the case of motor vehicles (Report #5), we estimate “average” total costs only, on the basis of the number of vehicles actually in use today. In the case of residential parking (Report #6), we estimate the total cost given the actual in-place (“average”) distribution of garage and offstreet parking spaces, and the total cost if the overall distribution of garages and offstreet parking spaces were the same as the distribution at newly constructed housing units. In the case of offstreet non-residential parking (Report #6), we estimate the total cost given the actual in-place (“average”) number of parking spaces, and the total cost if the number of spaces conformed to present parking space requirements per square foot of building space.

2.9 THE ACTUAL SOCIAL COST VERSUS THE OPTIMAL SOCIAL COST

The actual social cost of motor-vehicle use in any given year probably is not the economically "optimal” social cost -- the cost that would obtain if all prices were right and all items were priced, all markets were competitive, all actors were fully informed, and so on. One reason that it is not is because existing regulations (for example, emissions standards) are not designed strictly (or even partly) for economic efficiency. For example, in an economically perfect world, there would be taxes on emissions instead of the current gram-per-mile emission standards. In this world, cars might not have catalytic converters, which arguably are a result of the current emission standards. If they did not, then they would have a different cost, and the social cost of motor-vehicle use would be different than it actually was in 1990.

The point, then, is that the social cost of motor-vehicle use in 1990, which is what we estimate, is not necessarily what the cost would have been had all of the conditions of economic efficiency been fulfilled. Similarly, what the cost is likely to be in the future is not the same as what it would be if the conditions of economic efficiency were to be fulfilled, because the conditions almost certainly will not be fulfilled. (For example, there almost certainly will be regulations that are not economically efficient.)

2.10 NEW VERSUS EXISTING SYSTEMS

We estimate costs for existing transportation systems. To the extent that new systems are different from "typical" existing systems -- and generally they will be -- costs will be different. In fact, costs depend on design, usage, and operational characteristics that can be so variable that existing typical costs probably are of no use in assessing the costs and benefits of specific proposals. For example, the costs, and cost effectiveness, of public transit systems can vary over an enormous range, depending on technology, ridership, and other variables. The cost of older transit systems in dense cities is not much of a guide to the cost of new systems in more spread out metropolitan areas.

2.11 DYNAMIC AND SECOND-ORDER EFFECTS

Significant change in motor-vehicle use could have strong ripple effects on resource use, employment, prices, output, and consumption in many other sectors of the economy. In a perfect market economy, with full employment, completely mobile factors of production, instant adjustment of prices, and so on, some of these "second order" effects on prices, output, and so on would not be additional economic costs (net welfare gains or losses), but rather just "pecuniary" effects. However, there is at least one class of real additional welfare effects in other sectors in even a perfect market: the gain or loss of consumer and producer surplus due to changes in supply due to changes in factor prices due to changes in demand for those factors in the motor-vehicle sector. Moreover, in the real and imperfect market, the dynamic adjustments of the society and the economy to a significant change in motor-vehicle use are likely to result in real welfare effects that are not captured by an analysis of the proximate costs and benefits of a change in motor-vehicle use. In the real world, it takes time for prices to adjust, and for resources to move to their best uses in the face of new prices. During such adjustment, the economy will not be at its optimum efficiency point. In the real world there is unemployment, and unemployment in many sectors can be affected by changes in motor-vehicle use. In general, all of the second-order or dynamic effects depend, as always, on the specific conditions and scenario being analyzed, and are difficult to estimate. (For example, to incorporate employment effects in to the analysis, one must determine the effects on employment in all sectors, in all areas, over a long period of time, and estimate the opportunity cost of labor that would otherwise not be employed [accounting not only for the value of what the unemployed would otherwise be doing, but the psychological cost of being unemployed as well].) As Cropper and Oates (1992) note in regards to estimating the social costs of environmental regulations, "computable general equilibrium models, preferably those in which supply and demand functions have been econometrically estimated, may be needed.." (p. 722). We make no attempt to estimate such effects here.

2.12 EQUITY VERSUS EFFICIENCY

It is common in cost-benefit analysis to separate the question of who pays and who gains from the question of how much is paid. That is, equity usually is separated from efficiency, and economic costs are defined and measured without reference to their incidence. By this convention, whether a hidden cost of motor-vehicle use ultimately is borne by motor-vehicle users or by non-users, or by rich or by poor, is immaterial in the social-cost analysis. We follow this convention here, and do not distinguish between users and non users, or any between other groupings based on fairness, in estimating social cost. Thus, we do not care if the costs of motor-vehicle accidents are borne by those who caused them, or if "free" parking ultimately is paid for by those who use the parking. In fact, we do not discuss the incidence of costs at all.

Of course, to ignore equity is not to dismiss it as unimportant. In the political process it matters who wins and who loses, and politics determines transportation choices at least as much as does economics. Note, too, that the distinction between efficiency and equity is just a convention -- it is not logically required by the precepts of cost-benefit analysis. There is no fundamental reason why a cost-benefit analysis cannot quantify and incorporate concerns about equity: if equity matters, then it affects our welfare, and effects on welfare can be represented quantitatively (by one method or another) in terms of willingness to pay. For example, a simple way to incorporate equity considerations is to estimate the incidence of costs of benefits across various groups and assign weights to each group. Nevertheless, our analysis does not address questions of fairness.

2.14 THE COMPREHENSIVENESS OF THE ANALYSIS

We neither have identified every possible kind of cost of motor-vehicle use nor estimated every cost that we have identified. It probably would be relatively easy to name obscure, often overlooked, undoubtedly minor unpriced costs, such as payments to lawyers (not reimbursed by automobile insurance) for litigation services involving motor vehicles, and administrative expenses of government agencies with minor motor-vehicle related functions. We assume that the overlooked and neglected cost items are minor, but this is only an assumption.

It is possible that the Census' estimates of government expenditures on police protection, courts, the correctional system (jails, prisons, probation, and parole), and fire-protection, which we start with to estimate motor-vehicle related costs, do not include some significant costs items. However, given that the Census defines these cost-categories broadly (e.g., to include the cost of buildings, and the cost of administration), and that there are no police-protection, court, correctional, or fire-protection costs under any of the other governmental expenditure categories, we think that this is unlikely.

We also undoubtedly have overlooked some kinds of payments by motor-vehicle users for motor-vehicle use -- most likely fees, collected by the government from producers, that end up being incorporated into the price of motor-vehicle goods and services. The oil-spill liability tax is an example of this sort of charge, but one which we have counted. An example of a charge that we are aware of and in principle should count but have not is California's "air toxics hot-spot fee". The California Air Resources Board is required to collect fees from facilities subject to the "Hot Spots" Information and Assessment Act of 1987 in order to cover the Board's cost of administering the program. For fiscal year 1994 $5.6 million was allocated for the Hot Spots program (California Air Resources Board, 1993). Petroleum refineries are one of the major emitters of toxic air pollutants in the state, and so presumably pay a significant fee to cover a portion of the Board's administration and implementation cost. This fee probably is incorporated into the price of petroleum products, including gasoline. However, we are unable to estimate this cost. There may be other similar payments in California and other states.

2.15 OPTIMAL INVESTMENT IN NEW TRANSPORTATION SYSTEMS VERSUS OPTIMAL USE OF TRANSPORTATION SYSTEMS

It is useful to distinguish between efficient investment in new transportation systems, and efficient use of existing or planned transportation systems. A key analytical difference between investment and use is that, to *invest* efficiently in new systems, an analyst must estimate the social benefits as well as the social costs of the alternatives (or at least, do a social cost-effectiveness analysis), whereas to *use* transportation systems efficiently, it is necessary only that users be charged full marginal social-cost prices.

The economically preferred investment pattern is the one that maximizes the excess of social benefits over social costs. In order to identify this maximally beneficial pattern, somebody must perform an explicit social-cost analysis and an explicit social-benefit analysis, in which all of the costs and benefits of all of the alternatives are identified and quantified and monetized.

The best or most efficient use of a transportation system obtains when the marginal social value of use equals the marginal social cost. Now, if there are no external benefits of use -- that is, if there are no benefits that are not accounted for by users -- then the marginal social value is simply the value to the marginal users of the system, as privately assessed by the users themselves[19]. There is no need for an outside analyst to estimate the benefits of use, because the users do it themselves. If the social benefit of use equals the private benefit, and if we accept that the individual is the best judge of his own welfare, then, in order to ensure efficient use, we need only make sure that the user faces marginal social-cost prices.

[19]The question of external benefits is relevant to policy making because external benefits call for Pigouvian subsidies, which of course reduce the price of transportation, encourage greater consumption of transportation goods and services, and mitigate the behavioral impact of Pigouvian taxes.

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FIGURE 2-1. THE SOCIAL COSTS AND BENEFITS OF MOTOR-VEHICLE USE.

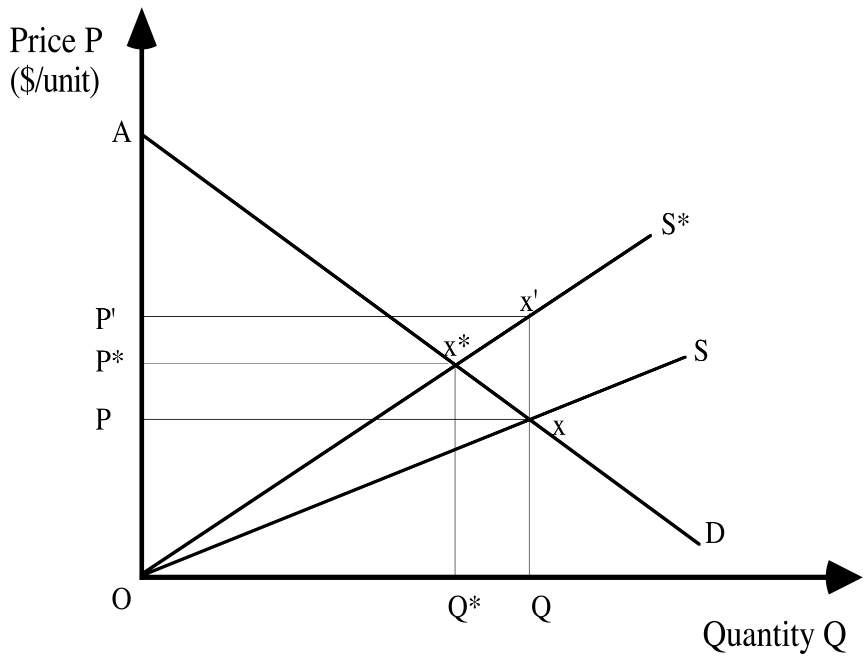

FIGURE 2-2. RISING, FALLING, AND CONSTANT MARGINAL COSTS.