8. COST EFFECTIVENESS OF THE VAVR PROGRAM

Programs to improve air quality are often assessed and compared in terms of cost per ton of emissions reduction. Such *cost-effectiveness ratios* are used as a convenient summary measure of program costs relative to benefits. In the case of ozone precursors—reactive organic gases and oxides of nitrogen—emissions are typically measured simply by adding tons per day of reductions in the two types of pollutants.

Such cost-effectiveness ratios are often claimed and widely believed to provide an accurate indication of economic efficiency consequences. They are useful, but they are not without their pitfalls.[1] First, tons of ROG plus NOx avoided can provide a very inaccurate indication of ozone reduction, no less of the health and other benefits sought by such programs. Second, it is often not possible to quantify and incorporate into the ratio other important social costs and benefits of a program, for example, concurrent reductions in pollutants other than ozone precursors. Third, the economic efficiency criterion ignores distribution of costs and benefits across income groups or regions, for example, which can be important policy considerations. Finally, in practice, cost-effectiveness analyses are often poorly implemented because of misunderstandings about the conceptual foundations of economic efficiency.

Conceptually, the relevant costs are resource costs, which are the social values of the resources consumed because of a program. Often, however, costs that are considered in a cost-effectiveness analysis are financial or budgetary costs. Moreover, because costs and benefits accrue over different time periods and with different time patterns, for a cost-effectiveness ratio to be meaningful, costs and benefits must be expressed in comparable units. The standard way of making them comparable is by discounting both costs and benefits to present value.[2]

In this section we use our predicted effects of the program to analyze the cost effectiveness of scrapping 75,000 vehicles per year between 2001 and 2010. We also compare our estimates—conceptually and numerically—to previous cost-effectiveness estimates of the M1 program and to estimates for other programs adopted to reduce ozone in the South Coast.

The resource costs of the VAVR program would include:

- administrative costs of the program including those associated with advertising, and inspecting, processing, and disposing of the vehicles,

[1]For a discussion of these issues in the context of programs to reduce emissions of ozone precursors from light-duty vehicles, see Dixon and Garber (1996, pp. 27–31).

[2]Discounting environmental benefits is controversial, but standard economic reasoning implies that benefits that accrue further in the future are, in fact, less valuable than benefits that accrue sooner, other things equal.

- the costs of monitoring and enforcing compliance with program rules, and
- the economic value of the vehicles destroyed net of any salvage value.

The economic value of the vehicles destroyed is the most subtle, most misunderstood, and perhaps the most important element of the calculation. Conceptually, what we want to measure is the social value of the transportation services lost when a serviceable vehicle is destroyed. Principles of economic-efficiency analysis suggest that this be measured by the value that the owner places on the vehicle, or equivalently, the amount of money the owner requires to surrender the vehicle, or the owner's "willingness to accept." "Costs of the vehicles" in a VAVR program are often misconceived in terms of financial costs, namely the purchase prices or bounties paid for the vehicles.[3] But since program participation is voluntary, purchase prices will typically exceed the values of the vehicles to the owners who surrender them for scrapping. The difference between the bounty received and the minimum amount that the owner would have been willing to accept is a *surplus benefit* received by the seller. This surplus is not a component of resource cost—it merely represents a transfer of value from the purchaser to the seller.

The social values of the scrapped vehicles cannot be predicted with precision. We attempt to gauge them by using empirical information about purchase prices in VAVR programs and the extent to which purchase prices may exceed willingness to accept.

Recent small-scale scrapping programs in the South Coast have purchased vehicles for between $500 and $600.[4] Alberini, Edelstein, Harrington, and McConnell (1994) report bounties of $500 in a small-scale program in Delaware. However, purchase prices in the M1 program are likely to be higher than these prices because of the somewhat stringent eligibility requirements, the need to attract many more vehicles per year, and the fact that the program will tend to increase used-LDV prices (by $66 according to our base-case estimates).

Kavalec and Setiawan (1997) provide evidence about bounty levels that is more pertinent to the SIP M1 program. Using an econometric model of vehicle choice by California households, they estimate required bounty levels of $785 in 1999 increasing to $965 in 2010 to attract 75,000 vehicles (at least 10 years old) per year in the South Coast.[5] In its analysis of the cost effectiveness of the VAVR program, CARB (1998a) considers purchase prices of $400, $600, and $800 per vehicle. The basis for these values is not discussed, but presumably this is the range that CARB

[3]Exceptions are Alberini, Edelstein, Harrington, and McConnell (1994) and Hahn (1995).

[4]A CARB 1,000-vehicle pilot program in the South Coast paid $500 per vehicle (personal communication with CARB staff, October 2000). Firms participating in the South Coast Air Quality Management District's VAVR program have paid up to $600 per vehicle. (Satzman, 1997).

[5]Sierra Research (1995) assumes a cost of $1,000 per vehicle, including administrative, testing and disposal costs. In addition, BAR's Consumer Assistance Program (described in Section 1) plans to purchase vehicles for $1,000 each (California Department of Consumer Affairs, 2000).

staff considered likely. Administrative costs are often assumed to be $100 per vehicle (see CARB, 1998a, p. 34; and Alberini, Edelstein, Harrington, and McConnell, 1994).

The surplus gained by each vehicle seller must be subtracted from the purchase price to estimate the social value lost by taking a vehicle out of service. Estimates of this surplus from a small pilot program and a large-scale, hypothetical program range from about 25 to 40 percent of the purchase price.[6]

In the face of this uncertainty about program costs, we proceed by specifying a plausible range for the resource costs per vehicle purchased by the program. This range is $500 to $1500. We think it very unlikely that the resource cost per vehicle will be below $500. Current small-scale programs are already paying more that this, and the purchase prices are expected to be higher in the SIP M1 program. Surplus to the sellers may account for as much as $125 to $200 of a $500 purchase price, but it will be largely offset by $100 for administration, testing, and disposal. We also think it very unlikely that the resource costs will exceed $1,500 per vehicle. For example, for resource costs to exceed $1,500, purchase prices would have to exceed $2,000 if sellers' surplus accounts on average for one-third of the purchase price, and administrative, testing, and disposal costs amount to $100 per vehicle. Purchase prices as high as $2,000 seem very doubtful in light of the estimates of Kavalec and Setiawan (1997) and our high-end estimate of price effects of $295 (see Table 7.3). Resource costs of $1,000 per vehicle appear to be a good ballpark estimate.

Table 8.1 combines three resource cost estimates with three estimates of the South Coast emissions effects of the program, namely, the estimates resulting from parameter values used in our base case and in our development of credible ranges.[7] Because benefits of the program continue after 2010, emissions reductions through 2020 are included in the calculations. Both costs, which cease to accrue after 2010, and emissions reductions are discounted to present value in 1999 using an annual discount rate of 4 percent.[8]

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[6]Alberini, Harrington, and McConnell (1994) estimate willingness to accept from a survey of participants in a small-scale program in Delaware and estimate that the total surplus to program participants was about 23 percent of purchase payments. Hahn constructs a supply curve of vehicles to a hypothetical scrapping program and infers a range of 26 to 40 percent (Hahn, 1995). See Dixon and Garber (1996, p. 174) for discussion.

[7]We do not include predicted emission reductions due to the program in the rest of California because the primary purpose of the VAVR program is to reduce emissions in the South Coast. The benefits outside the South Coast are an example of the kind of benefits that are relevant for policy but are often not incorporated in calculated cost-effectiveness ratios.

[8]Discount rates of 3 to 5 percent have commonly been used in calculating the cost effectiveness of emissions-reduction programs for light-duty vehicles (see Dixon and Garber, 1996, p. 263).

Table 8.1

Cost Effectiveness of Scrapping 75,000 Older Vehicles per Year from 2001 to 2010 in the South Coast (dollars per ton of ROG plus NOx, 1999 dollars)[a,b]

	Resource Cost ($/vehicle)		
Effect of Program on Emissions	500	1,000	1,500
Top of credible range	3,700	7,500	11,300
Base case	6,700	13,400	20,100
Bottom of credible range	11,100	22,200	33,300

[a] Costs and emissions reductions discounted using a real discount rate of 4 percent.
[b] Includes emissions effects through 2020.

Assuming resource costs of $1,000 per vehicle, costs for the entire 10-year VAVR program are estimated to range from $7,500 to $22,200 per ton. The cost-effectiveness ratios are proportional to the assumed cost per vehicle. For example, costs per ton fall by 50 percent when resource costs are assumed to equal $500 per vehicle and increase by 50 percent when resource costs are assumed to be $1,500 per vehicle.[9] Thus, the figures in Table 8.1 can be easily adjusted to consider the consequences of other assumptions about resource costs per vehicle scrapped through the VAVR program.

The predicted emissions effects of the program increase and then decrease over time. Moreover, the LDV fleet is projected to become cleaner over time in terms of emissions per mile. How does the predicted cost effectiveness of the program change over time? Assuming base-case parameter values and resource costs of $1,000 per vehicle, cost effectiveness for the first year of the program (2001) is estimated at $10,200 per ton compared with $13,400 per ton for the 10-year program (Table 8.1).[10] And, while a decision need not be made any time soon about extending the program beyond 2010, our estimates suggest that the cost per ton of extending the program by one year (namely, through 2011) would be $17,400 per ton.[11]

As detailed presently, our estimates of cost per ton are somewhat higher than those reported by others who have considered variants of the SIP M1 program. Numerical comparisons

[9]Cost-effectiveness results are not very sensitive to varying the discount rate from 3 to 5 percent. For example, using base-case emissions reductions and resource costs of $1000 per vehicle results in cost-effectiveness ratios of $13,328, $13,421, and $13,515 when discount rates of 3, 4, and 5 percent are used, respectively.

[10]Cost effectiveness in the first year is calculated by simulating the emissions effects of a program that lasts only one year (2001).

[11]Cost per ton of extending the program one year is calculated using the present values of the incremental costs and incremental emissions reductions of a program operated from 2001 through 2011 rather than from 2001 through 2010.

should be made cautiously, however, because of differences in the features of the programs being studied, what effects of the program are considered, and how cost effectiveness is defined. Reported estimates of cost effectiveness range from $4,200 to $6,700 per ton of ROG plus NOx in Kavalec and Setiawan (1997) for a program that scraps 75,000 vehicles (10 years old and older) from 1999 through 2010.[12] Several factors reduce their cost-per-ton estimate relative to ours: administrative, testing, and disposal costs are not included; they do not allow for any increases in used-LDV prices because of the program; emissions benefits are not discounted; and emissions reductions are calculated assuming that the Smog Check program is wholly ineffective. They do not net out seller surplus, however, and this tends to increase their cost-per-ton estimate relative to ours. Sierra Research (1995) calculates a cost-effectiveness ratio of $8,200 per ton for a similar-sized program.[13] CARB's estimates range from $2,600 per ton to $7,600 per ton for a range of purchase prices plus administrative costs of $500 to $900 (CARB, 1998a).[14] CARB, however, considers cost effectiveness only for vehicles purchased in 1999, which conceptually corresponds most closely to our estimate of cost effectiveness in the first year of the program ($10,200 per ton).

What do our estimates suggest about the attractiveness of implementing the SIP M1 program? First, our analysis suggests the cost effectiveness of the program will be similar to that of many already implemented elements of the ozone-reduction strategy for light-duty vehicles in California. More specifically, Table 8.2 reports cost-effectiveness ratios calculated for several other elements of California's strategy as Garber and Dixon (1996) were best able to determine in 1996 from a review of existing studies, synthesis, and further modeling.[15] As can be seen by comparing Tables 8.1 and 8.2, even our highest cost-per-ton estimate of $33,300 for the VAVR program (Table 8.1) is below the high end of the ranges for many of the *existing* programs in California's strategy (Table 8.2).

Second, and much more important for policy purposes, the cost effectiveness of the VAVR program is likely to be quite good relative to other *still-available* options for reducing emissions of ozone precursors in the South Coast. In particular, the

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[12]This range is for estimates using discount rates of 3 and 6 percent. Kavalec and Setiawan (1997) also simulate effects of a program restricted to vehicles at least 20 years old, but this program involves scrapping fewer than 40,000 vehicles per year through 2006, making those results especially difficult to compare with ours. (See Kavalec and Setiawan, 1997, Table 10.)

[13]This estimate does not discount costs or emissions, and does not net out seller surplus. It also assumes that the LDVs purchased by the program are "high emitters."

[14]CARB does not discount emissions and includes sellers' surplus in its cost estimates.

[15]The figures in Table 8.2 are expressed in 1995 dollars. To make them more comparable with the cost-effectiveness estimates in Table 8.1, which are expressed in 1999 dollars, they could be increased by about 9 percent. (This is the 1995 to 1999 increase in the Consumer Price Index—All Urban Consumers. Source: Bureau of Labor Statistics, data accessed from http://146.142.4.24/cgi-bin/surveymost on March 21, 2000.)

Table 8.2

Estimated Cost Effectiveness of Selected Elements of California's Ozone Reduction Strategy for LDVs (1995 Dollars per ton of ROG plus NOx)

Element of Strategy	Cost-Effectiveness Ratio
On-Board Diagnostics II	2,000–15,000
Low Emissions Vehicles	1,000–38,000
Transitional Low Emissions Vehicles	3,000–40,000
California Phase 2 Gasoline	9,000–46,000
Ultra Low Emissions Vehicles	22,000–48,000

Source: Dixon, Garber, and Vaiana, 1996, p. 15.

programs that have already been implemented are projected to leave California far short of meeting federal and state clean-air goals, and the SIP commits California to identifying and implementing additional measures to reduce LDV emissions in the South Coast.[16] The key policy question is whether a VAVR program should be among the policy measures to be implemented in the future. Our estimates suggest that the answer is yes because options for the future are likely to be less cost effective than programs that have already been implemented and, thus, less cost effective than a VAVR program. Specifically, while it is hoped that new technologies and additional creative thinking will provide California with attractive new options for reducing emissions of ozone precursors, it is important to recognize that the programs that have already been implemented are by and large those politically feasible programs that have been identified and have appeared to be most cost effective to date.[17] Thus, it seems unduly optimistic to base policy on a presumption that air-quality goals for 2010 can be met with programs that are more cost effective than the VAVR program appears to be.

Not only does it seem likely that a VAVR program would be more cost effective than other programs that may be required to achieve compliance with air-quality regulations, the program also looks reasonably attractive in terms of economic efficiency. Specifically, our cost-per-ton estimates in Table 8.1 are in the general range of estimates of the social benefits per ton of reducing ROG and NOx emissions in the South Coast. For example, Dixon and Garber (1996, pp.

[16]For example, CARB's State Implementation Plan for Ozone contains a "Black Box" for mobile-source emissions reductions in the South Coast Air Basin from programs that are yet to be identified. After adoption of the LEVII program in 1998, CARB estimated that 43 tons per day remain in the Black Box (CARB, 1998b, pp. 1–2).

[17]Many economists favor policies that discourage pollution through altered prices such as emission-based vehicle registration fees (Harrington, Walls, and McConnell, 1995), or taxes on gasoline, engine size, or vehicle age (Fullerton and West, 1999). No matter what the merits of such policies, it seems that they are not being seriously considered for implementation in California because they are anticipated to be very unpopular.

21–22, 364–370) concluded from a review of existing literature that benefits of reducing ROG and NOx emissions in the South Coast are likely to exceed $5,000 per ton, perhaps by a substantial amount, but are probably less than $25,000 per ton.[18] Only under rather pessimistic assumptions do our estimates of cost-per-ton for the VAVR program in Table 8.1 exceed $20,000, and our base-case estimates of emissions effects combined with our best guess of resource costs of $1,000 per vehicle imply a cost per ton of $13,400.

In sum, our analysis suggests that the planned VAVR program—or an improved variant of it—is an attractive means for promoting air quality in the South Coast despite the fact that it may be somewhat optimistic to expect emissions benefits as large as the 25 tons per day in 2010 projected in California's SIP for Ozone.

[18]These figures are expressed in 1995 dollars. They should be increased by about 9 percent to make them comparable with figures in Table 8.1.