7. RANGES OF EFFECTS OF THE VAVR PROGRAM

The previous section presented point estimates of effects of a VAVR program that removes 75,000 older vehicles per year for 10 years from the LDV fleet in the South Coast. These estimates are, however, subject to many potential sources of error, and the precise effects of the program cannot be predicted with great confidence. In this section we explore various sources of uncertainty about program effects and estimate ranges into which the price and emissions effects of the program appear very likely to fall.

We begin by examining the sensitivity of our base-case predictions to changes in individual features of the model. This allows us to gauge the importance of various factors in determining effects of the VAVR program and to develop a preliminary sense of the degree of uncertainty about sizes of actual program effects. Next, we construct scenarios combining model assumptions that all tend to produce either large or small predicted effects on used-LDV prices and South Coast emissions, to gauge the degrees to which these effects might plausibly deviate from the base-case predictions.

SENSITIVITY TO CHANGES IN INDIVIDUAL MODEL FEATURES

Two types of sensitivity analyses are discussed in this section. First, we examine the sensitivity of the results to varying six individual parameters over the ranges of values presented in Section 5. We first discuss two parameters that turn out to have substantial effects on predictions of both used-LDV prices and emissions levels, and then turn to four parameters that mainly affect prices. We then examine the sensitivity of the predictions to three fundamental, maintained features of the model.

The results of the sensitivity analyses over individual parameter values are presented in Table 7.1. Each set of rows reports estimates for the base case (to aid comparison) and for the indicated alternative assumptions, while leaving all other features of the model as they are in the base case. The columns of the table present estimated program effects on four key outcomes in the South Coast in 2010: the average price of used LDVs, the total number of LDVs on the road, the percentage of LDVs that are at least 15 years old, and daily emissions of ROG plus NOx.

Table 7.1

Sensitivity of Predictions of Program Effects in South Coast in 2010 to Changes in Individual Parameter Values

	Used LDV Price ($)	Light-Duty Vehicles (thousands)	Percentage of Older Vehicles	Emissions from LDVs (tpd[a] ROG+NOx)
Parameters That Affect Both Price and Emissions				
Size of program				
50,000 per year	43	-40	-0.8	-9
75,000 per year (base case)	66	-60	-1.1	-13
100,000 per year	88	-80	-1.5	-18
Expected life of scrapped vehicles				
2 years	39	-35	-0.7	-8
3 years (base case)	66	-60	-1.1	-13
5 years	126	-113	-2.1	-27
Parameters That Mainly Affect Price				
Elasticity of demand for new vehicles				
-0.8	69	-63	-1.1	-13
-1.0 (base case)	66	-60	-1.1	-13
-1.2	63	-57	-1.1	-13
Elasticity of demand for used vehicles				
-0.25	106	-43	-1.2	-14
-0.50 (base case)	66	-60	-1.1	-13
-0.75	47	-66	-1.1	-13
Initial average used-LDV price				
$4,500	57	-63	-1.1	-13
$5,500 (base case)	66	-60	-1.1	-13
$6,500	75	-57	-1.1	-13
Average new-LDV price				
$20,000	64	-58	-1.1	-13
$22,500 (base case)	66	-60	-1.1	-13
$25,000	68	-62	-1.1	-13

[a]Tons per day.

Sensitivity to Parameters That Affect Both Price and Emissions

Program Size. The first set of rows in Table 7.1 reports results varying the number of LDVs scrapped per year by the VAVR program. The effect of the program on used-vehicle prices and emissions in the South Coast in 2010 are roughly proportional to the size of the program over the range of program sizes examined. For example, increasing the program size by one-third, from 75,000 to 100,000 vehicles per year, increases the price effect by one-third, from $66 to $88, and increases emissions benefits from 13 to 18 tons per day, about one-third. Decreasing program size from 75,000 to 50,000 vehicles changes the predicted price and emissions effects by about the

same amounts, but in opposite directions. These estimates suggest that the SIP target for the M1 program of 25 tons per day in 2010 would require a program that scraps considerably more than 75,000 vehicles per year.

Expected Life of Vehicles Scrapped Through the Program. Predicted effects of the program are quite sensitive to our alternative assumptions about the average expected life of vehicles scrapped through the program. Predicted effects on both price and emissions decrease as the expected life of vehicles scrapped through the program falls. This result makes sense intuitively: The shorter the expected lives of the LDVs scrapped through the program, the sooner they would have been scrapped naturally and the less the program actually accelerates LDV retirement and affects vehicle markets. The estimates indicate that a VAVR program can generate substantial emissions reductions even if the vehicles scrapped have rather short expected remaining lives. In particular, for expected lives of two years—compared with three years as assumed by CARB and in our base case—our prediction is that the program would reduce emissions by 8 tons per day in the South Coast in 2010. While a program that attracts vehicles that are more representative of all age-eligible vehicles on the road would have greater emissions effects, it is likely that this would require higher bounties and higher emissions-credit procurement costs because LDVs with longer remaining lives should have more value to their owners. Thus, it may or may not be preferable to target LDVs with longer remaining lives.

Sensitivity to Parameters That Mainly Affect Price

Elasticity of Demand for New LDVs. Varying the assumed elasticity of demand for new LDVs from -0.8 to -1.2 has a minor impact on predicted program effects on used-LDV prices. Specifically, varying the value of this elasticity by 0.2 in either direction from its base-case value changes the year-2010 price prediction by only $3 per used LDV relative to a base-case prediction of $66. Moreover, varying the assumed price elasticity of new LDVs leaves the predicted effects of the program on emissions essentially unchanged.

Elasticity of Demand for Used LDVs. Varying the price elasticity of demand for used LDVs from -0.75 to -0.25 more than doubles the predicted effect of the program on used-LDV prices in 2010. This is because when demand is less elastic, a larger increase in price is required to reduce quantities demanded sufficiently to clear LDV markets when available LDV supplies are decreased by a given amount. At $106, the maximum price effect is just about 2 percent of the average used-LDV price in the base case ($5,500). A larger (absolute) price elasticity leads to a larger decrease in the size of the LDV fleet in the South Coast because the reduced tendency for used-LDV prices to increase leads to fewer induced new-LDV sales and less in-migration of LDVs into the South Coast. The effects on emissions of varying the elasticity of demand for used LDVs is about one ton per day.

Average Used-LDV Price in 1999. In the model, we parameterized demand in terms of a constant price elasticity. Given a value for the elasticity of demand, proportionate price effects can be calculated from proportionate effects on LDV stocks. The baseline price to which such a proportionate price effect applies—namely, the average price of used LDVs—is subject to considerable uncertainty, however. Varying the initial price of used LDVs from $4,500 to $6,500 produces a range of predicted price effects in 2010 of $57 to $75 per used LDV, which is about 1.2 percent of the corresponding initial assumed prices.[1]

New-Vehicle Price. Higher new-vehicle prices mean that any given program effect on used-LDV prices is smaller relative to new-vehicle prices and thus has less impact on new-vehicle sales. Varying our assumption about the average price of new LDVs from $20,000 to $25,000 produces quite small changes in predicted effects of the program on used-LDV prices, numbers of vehicles, and emissions.

Sensitivity to Fundamental Model Features

Table 7.2 summarizes the results of changing three basic features of our model. The three alternative assumptions considered are (a) migration of LDVs into the South Coast is foreclosed; (b) the VAVR program affects prices and migration only of LDVs that are at least 15 years old; and (c) new-LDV sales are unaffected by the VAVR program. Each of these alternative assumptions is implausible. However, considering the effects of these assumptions helps gauge the degree to which the three maintained assumptions affect our results.

Table 7.2

Sensitivity of Predictions of Program Effects in South Coast in 2010 to Changes in Basic Model Features

	Used LDV Price ($)	Light-Duty Vehicles (thousands)	Percentage of Older Vehicles	Emissions from LDVs (tpd[a] ROG+NOx)
Base case	66	-60	-1.1	-13
No migration into the South Coast	133	-143	-1.3	-16
Price effect and migration limited to age-eligible vehicles	21	-74	-0.5	-4
New-LDV sales unaffected by program	83	-79	-1.1	-13

[a]Tons per day.

[1]These percentages are not precisely the same because the percentage changes in LDV stocks also differ in the two cases.

LDV Migration into the South Coast. Migration of LDVs into the South Coast plays an important role in our analysis. In all cases considered to this point of the analysis, we assumed that used vehicles migrate to eliminate any used-LDV price differentials between the South Coast and the rest of California. For the reasons detailed in Section 2, price equalization appears to be a reasonable approximation to reality and an analytically attractive equilibrium condition. But assuming price equalization could tend to overpredict the amount of in-migration in response to the program. No empirical basis is apparent for altering the model to allow degrees of in-migration that would be insufficient to equalize used-LDV prices in the South Coast with those in the rest of California.[2] To examine the potential importance of lesser degrees of in-migration and to gauge the extent to which in-migration undermines the potential benefits of a VAVR program, then, we go to the opposite extreme from our price-equalization equilibrium condition and compare predictions from the base case to an implausible alternative scenario in which in-migration is impossible.

As can be seen from Table 7.2, if in-migration were precluded, the predicted effect of the program on used-LDV prices in 2010 is $133, or just about twice that in the base case. Assuming away in-migration possibilities also leads to a major change in the predicted effects of the program on the size of the LDV fleet in the South Coast, and moderate effects on the proportion of the fleet at least 15 years old and the emissions benefits of the program. The directions of these changes in predictions all make sense intuitively. Specifically, without in-migration: (a) the program would reduce the size of the South Coast LDV fleet by a larger amount; (b) the program improves the age composition of this fleet even more because larger effects on used-LDV prices trigger more new-LDV sales; and (c) the larger age-composition improvement contributes to larger emissions benefits. The difference between predicted emissions benefits of 13 tons per day in the base case and 16 tons per day when we assume that in-migration is precluded indicates that in-migration undermines the potential emissions effects of the VAVR program in important, but not profound, ways. The effect on emissions is not profound because, as discussed in Section 6, much of the in-migration would be by newer LDVs.

Vintages of LDVs Subject to Price and In-Migration Effects. As explained in Section 2, the VAVR program should be expected to increase prices of used LDVs of all vintages and induce in-migration of LDVs of all vintages even though LDVs are eligible for the program only if they are at least 15 years old. In short, the age-eligibility requirement of the VAVR program does not

[2]For example, we know of no empirical information concerning the extent of systematic differences, if any, in used-LDV prices in the South Coast and elsewhere in California. More important, current price differentials are likely to be largely uninformative about the differentials that might exist if LDV markets are subjected to the kind of disruption that would be caused by a VAVR program like the one modeled here.

alter the fact that the markets for used LDVs of *all* vintages and locations are interdependent. Nonetheless, the intuition of many previous analysts of VAVR programs has been that price and in-migration effects will be largely, if not totally, limited to age-eligible vehicles.[3] In our analyses up to this point, we employed the assumption that the effects of the VAVR program on used-vehicle prices are the same dollar amount for all vintages. While, as detailed in Section 2, this assumption appears to provide a useful approximation to reality, it is only an approximation, and it is possible that effects of the program on used-LDV prices will be somewhat larger in dollar terms for older LDVs. We see no basis for assuming or estimating the degrees of any such cross-vintage differences in price effects. Instead, we examine the predictions of the model by assuming (implausibly) that the program has no effects on prices or in-migration of LDVs less than 15 years old. To develop these projections, we assume that the price elasticity of demand for older LDVs is -0.75[4] and the average price of older LDVs is $600.[5]

The results are reported in the third row of Table 7.2. As can be seen from the table, assuming that the VAVR program affects only the markets for older LDVs, the absolute price effect for older LDVs is predicted to be about one-third of that for the base case ($21 versus $66), but higher in percentage terms (3.5 percent of $600 versus 1.2 percent of $5,500). These smaller absolute-price effects reflect the quite low average price of older LDVs ($600 versus $5,500 for all used LDVs in the base case) and the more elastic demand for older LDVs (-0.75 versus -0.5 for all used LDVs in the base case), the effects of which overpower the fact that the VAVR program reduces the number of older LDVs by a larger percentage than the percentage reduction in all used LDVs.[6] Assuming that price and in-migration effects are limited to age-eligible vehicles reduces the predicted emissions effects of the program by more than two-thirds, namely, from 13 tons per day in the base case to 4 tons per day. However, we anticipate that any tendency for price and migration impacts of the program to be greater for older vehicles will have minor effects on program benefits.

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[3]See, for example, Dixon and Garber (1996, p. 190), Moyer, Pera, and Wool (1995, p. 2), and CARB (1998a, p. 23).

[4]Recall that we assumed in the base case that the price elasticity of demand for all used LDVs is -0.5. Since age-eligible (15 year old and older) LDVs are a subset of all used LDVs, the demand for age-eligible LDVs should be more elastic than that for all used LDVs.

[5]The value of $600 was developed as follows: For LDVs 15 and more years old, the average trade-in and retail prices developed from the Kelley Blue Book data (see Section 5 and the appendix) are $456 and $1,596, respectively. In averaging these figures, we put predominant weight on the trade-in value because we expect that many age-eligible vehicles are not in even good condition (as assumed in constructing the trade-in price series) and only a very small fraction of them are in excellent condition (as assumed in constructing the retail price series).

[6]The former percentage change underlies predicted price effects in the present case, and the latter underlies predicted price effects in the base case.

Finally, while we do not believe that this case is indicative of the actual effects of a VAVR program, it is important to recognize that if migration of LDVs into the South Coast is disproportionately composed of older LDVs, this would lead to larger reductions in LDV emissions in the rest of California. For example, for the extreme case currently under discussion, the predicted emissions reductions for California excluding the South Coast are 11 tons per day, as compared with 3 tons per day in the base case.

Response of New-LDV Sales to Price Increases for Used LDVs. Increases in new-LDV sales in response to higher used-LDV prices also play an important role in the analysis. Predicted increases in new-LDV sales were based on assuming that prices of new LDVs are—because of competitive market conditions—determined by costs of (producing, transporting, selling, etc.) new LDVs. Here we consider the alternative, but implausible, assumption that new-LDV sales are unaffected by the program, to explore the extent to which the base-case predictions are affected by additional new-LDV sales.

The last row of Table 7.2 shows that predicted program effects on used-LDV prices and the size of the South Coast LDV fleet are moderately sensitive to program-driven increases in new-LDV sales. Specifically, the alternative assumption produces a predicted price effect for used LDVs in 2010 of $83 compared to a base-case prediction of $66 and a predicted reduction of 79,000 in the size of the South Coast fleet compared with a base-case prediction of 60,000. Most important, perhaps, is the fact that predicted emissions effects are almost entirely insensitive to this assumption.

CREDIBLE RANGES FOR PRICE AND EMISSIONS EFFECTS

Predicting effects of the program on used-LDV prices and South Coast emissions is subject to many sources of uncertainty. The sensitivity analyses reported above examine several of these sources, but only one of them at a time. We now develop information about the ranges in which we can be reasonably confident that the price and emissions effects will fall. This analysis involves considering effects on our predictions of varying five parameters jointly from their base-case values.

Our goal is to develop ranges in which effects of the VAVR program on used-LDV prices and South Coast emissions can be expected to fall with high probability, much closer to 1 than to 0.5, say. We proceed by constructing what we call *credible* ranges for price and emissions effects using two sets of parameter values to develop the end points of the ranges. One scenario produces relatively small predicted price and emissions effects, and the other scenario produces relatively large ones.

To construct the scenarios, we maintain the fundamental features of the model that we believe are the best workable approximations to reality. Specifically, we maintain the base-case assumptions that (a) the VAVR program scraps 75,000 LDVs per year, (b) new-LDV prices are unaffected by the program, (c) the program increases prices of used LDVs of all vintages by the same amount, and (d) vehicle migration equalizes used-LDV prices across the state. We then vary the five parameters examined in Table 7.1 other than the program size over the ranges used for the individual sensitivity analyses, combining values that all tend to push predicted price and emissions effects in the same direction. Panel A of Table 7.3 details the parameter values comprising the base-case (for comparison purposes) and the two alternative scenarios. The parameter values detailed in the middle column all tend to produce relatively small predicted effects of the program on used-LDV prices and South Coast emissions reductions. The parameter values detailed in the last column all tend to produce relatively large predicted effects. In jointly varying all five parameters over what we consider to be their plausible ranges, we believe that our credible ranges are wide enough to compensate for uncertainty due to the approximations involved in the maintained features of the model.

First consider credible ranges for effects of the VAVR program on used-LDV prices and South Coast emissions for the year 2010. These ranges are developed from estimates reported in Panel B of Table 7.3. The first set of alternative parameter values (middle column) leads to the predictions that in 2010 used-LDV prices will be $22 higher and South Coast emissions of ROG plus NOx will be lower by 8 tons per day because of the VAVR program. The second set of alternative parameter values (last column) leads to predictions for 2010 of price effects of $271 per used LDV and emissions reductions of 28 tons per day. Thus, our credible range for the effect of the program on used-LDV prices in 2010 is $22 to $271 per LDV, and our credible range for emissions effects in 2010 is 8 to 28 tons of ROG plus NOx per day.

We have paid particular attention to the year 2010 because that is the deadline for the South Coast to comply with federal air quality standards. But program effects on prices and emissions in other years also affect the well-being of Californians and are thus of interest for policy purposes. As discussed in Section 6, our base-case parameter values lead to the prediction that the largest price and emissions effects of the program will occur before 2010, specifically, in the year 2005 (Figures 6.1 and 6.4).

Table 7.3

Alternative Scenarios and Implied Credible Ranges for the Effects of the Program in the South Coast

	Base Case	Small Program Effects	Large Program Effects
A. Parameter Values[a]			
Expected life of scrapped vehicles (years)	3	2	5
Elasticity of demand for new vehicles	-1.00	-1.20	-0.80
Elasticity of demand for used vehicles	-0.50	-0.75	-0.25
Initial average used-LDV price	5,500	4,500	6,500
Average new-LDV price	22,500	20,000	25,000
B. Program effects in the South Coast in 2010			
Used-LDV price ($/vehicle)	66	22	271
Emissions (tons of ROG plus NOx per day)	-13	-8	-28
C. Program effects in the South Coast during year with largest effects			
Year	2005	2004	2008
Used-LDV price ($/vehicle)	79	27	295
Emissions (tons of ROG plus NOx per day)	-19	-12	-30

[a] Other parameter values and all basic model features are as specified in the base-case.

Thus we now consider credible ranges for the largest price and South-Coast emissions effects of the program in whatever year they might occur. These credible ranges are developed from estimates reported in the bottom panel of Table 7.3. For the parameter values that lead to predictions of relatively small price and emissions effects (middle column), the largest predicted price and emissions effects occur in the year 2004. For the parameter values that lead to predictions of relatively large price and emissions effects (last column), the largest predicted price and emissions effects occur in the year 2008. Using the estimates reported in the bottom panel of the table, our credible range for the largest price effect of the program is $27 to $295. Our credible range for the largest emissions effect of the program is a reduction of 12 to 30 tons of ROG plus NOx per day emitted from LDVs in the South Coast.

What do these estimates suggest about the significance of the effects of the VAVR program on used-LDV prices? Suppose that the price effect were as large as our largest estimate of $295. First, even this estimate of price effects—our largest—is much smaller than has been suggested by others. Second, this estimate suggests that average used-vehicle prices would be at most 5 percent

higher[7] than they would be without the program. Third, a price increase of almost $300 would not be inconsequential, however, to some households.[8] We return to this issue in Section 9.

What do our estimates suggest about emissions effects of the program and the likelihood of reaching the SIP goals for the program in 2010? Our estimates suggest that emissions effects in 2010 will almost certainly be at least 8 tons per day. However, we view this value as very, and probably unduly, pessimistic. Not only is the prediction based on the seemingly pessimistic assumption that the expected life of vehicles scrapped through the VAVR program will be only 2 years, perhaps much more important is the fact that at least four of our maintained assumptions tend to make the model err to the side of underpredicting emissions reductions. In particular, we have made the following assumptions:[9]

- The program attracts the same proportion of LDVs of each eligible model year despite the availability of more emissions-reduction credits for scrapping older LDVs, which should translate into higher bounties for increasingly old, and generally dirtier, LDVs.
- Vehicles sold to the program are no dirtier than other vehicles of the same vintage despite the fact that the program may attract LDVs with above-average emissions for their age, for the same reason (i.e., lower value to their owners) that the program should be expected to attract vehicles with lower-than-average expected lives.
- Older vehicles are as prone to migrating into the South Coast as newer LDVs despite the fact that distance-sensitive transactions costs are likely to be higher for older LDVs.
- Total vehicle miles traveled (VMT) by LDVs in the South Coast will be unaffected by the program despite the fact that the program will reduce the number of LDVs in the South Coast.

Thus, we believe that the actual South Coast emissions effects of the program in 2010 are likely to be closer to 28 tons per day (the top of our credible range) than to 8 tons per day (the bottom of the range).

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[7]Based on an average used-LDV price of $6,500, which is assumed in developing the high end of the credible ranges for price effects.

[8]For example, a price effect of $295 would represent almost a 50 percent increase in our estimated average price of $600 for age-eligible LDVs.

[9]None of these assumptions affects our price-effect predictions.