4. PREDICTING EFFECTS OF THE PROGRAM: OVERVIEW

This section provides an overview of our methods for predicting effects of the program. Details are presented in Section 5.

The outcomes of primary interest are

- prices of used LDVs in the South Coast and in the rest of California,
- numbers of LDVs operating in the South Coast,
- age distribution of LDVs operating in the South Coast, and
- quantities of daily ROG and NOx emissions from LDVs operating in the South Coast.

We develop predictions of these outcomes over the years 2001 to 2020 and assess ranges of uncertainty for our predictions.

There is no precedent for the VAVR program planned for the South Coast.[1] Most important, VAVRs operated to date have been much smaller and shorter-lived. Thus, effects of the program cannot be estimated by relying on analysis of historical data.

Instead, we construct quantitative models of the outcomes of interest—with parameter values calibrated using available empirical information—and compute simulations to serve as predictions. Degrees of uncertainty about the predictions are assessed by sensitivity analysis, which involves rerunning the model using alternative parameter values. These alternatives are chosen to span the range of conditions that would plausibly characterize the environment in which the VAVR program will operate in the real world.

This section is structured as follows. We first comment on the utility of using simulation models to analyze the issues of interest. We then define what we mean by the "effects of the VAVR program." The section concludes with discussions of the elements of our model and our approach to gauging the degrees of uncertainty about our predictions.

COMPLEXITY AND SIMPLIFYING ASSUMPTIONS

In the model, we distinguish vehicle stocks in each year both by vintage (model year) and geographic location (the South Coast and elsewhere in California). Thus, there are several outcome variables in any year. Moreover, these outcomes are jointly determined (logically interconnected) in any year and also linked over years. Thus, there are too many variables and

[1]Moreover, if a program similar to the one planned for the South Coast had been operated in a different region, the effects of that program might not be very revealing about the effects of the South Coast program because of differences in such factors as the sizes of the two regions, demand conditions for LDVs, durability of LDVs, and the age and geographic distributions of LDV stocks.

their interconnections are too complex for intuition or simple calculations to provide a reliable guide for policy. In response to this complexity, we analyze the effects of the program by constructing models of the program and the market environment in which it will operate and use the models and computer-aided calculations to derive predictions about the effects of the program.

Models are, by definition, simplifications of reality. Simplification is useful—indeed, necessary—when the aim is to predict the outcomes of complex processes.[2] The model is composed of several equations representing various forces or phenomena suggested by the conceptual analyses described in Section 2. Empirical information is used as available to assign numerical values to the parameters of these equations.

It is most useful for policy purposes to develop predictions that can be compared to official CARB estimates of emissions effects. Thus, the sizes of the markets represented by the model are specified so that the model predicts emissions levels in the South Coast in the absence of the program that are comparable to CARB predictions. This involves building into the model, as explained in the next section, growth over time.

PREDICTED EFFECTS OF THE VAVR PROGRAM: DEFINITIONS

The VAVR program that we analyze is specified to represent, despite remaining uncertainties about various details, the program that is planned for implementation. Specifically, the program is assumed to involve voluntary scrapping of 75,000 age-eligible LDVs (LDVs at least 15 years old) every year from 2001 through 2010.

For any set of parameter values, the model is run, and predictions are computed, alternatively assuming the following:

- No LDVs are scrapped through the program in any year. We refer to this as the *without-program* scenario.
- 75,000 South-Coast LDVs are scrapped through the program each year from 2001 through 2010. We refer to this as the *with-program* scenario.

[2]Models allow (a) a complex phenomenon to be decomposed into pieces (assumptions) that can be represented reasonably accurately by drawing on empirical information, theory, and intuition; (b) logical implications of the pieces to be rigorously derived (e.g., through computer-aided calculations); (c) assumptions to be varied to assess the sensitivity of predictions to assumptions; (d) the reasonableness of the assumptions, and thereby the likely accuracy of the predictions, to be assessed; and (e) the appropriateness of the interpretations and conclusions to be judged.

While the program is assumed to cease buying and scrapping vehicles after 2010, effects of the program persist after that year because scrapping in earlier years affects vehicle stocks, prices, and emissions in later years.

For each scenario, the model generates predicted values for various outcomes for every year from 2001 through 2020. The *effect of the program* on any outcome in any year is defined as the value predicted for that outcome in that year with the program (i.e., if the program were implemented) minus the value predicted for that outcome in that year without the program (i.e., if the program were not implemented). For example, for a given model run (set of assumptions), the predicted effect of the VAVR program on the average price of used LDVs in the South Coast in the year 2010 is the predicted value of that average price in 2010 with the program minus the predicted value of that average price in 2010 without the program.

ELEMENTS OF THE MODEL

For each year beginning with 2001, the model calculates average used-LDV prices, quantities of LDVs of different model years located in the South Coast and in the rest of California, and LDV emissions levels in the two regions, all of which are interpreted as pertaining to the last day of the year. To represent the average value of any of these quantities during a calendar year, we report the average of the end-of-year values for that year and for the previous year.

Figure 4.1 provides a schematic overview of the model and how end-of-year predictions are computed. Under either scenario, the year starts with a set of LDV stocks, namely, the number of LDVs of each vintage assumed to be present in the South Coast and in the rest of California at the beginning of the year. In the scenario with the VAVR program, the operation of the program is represented in each year from 2001 to 2010 by deducting from the LDV stocks in the South Coast 75,000 LDVs that are at least 15 years old during that calendar year. The distribution of model years of the LDVs scrapped through the program is specified by assumption. In the without-program scenario LDV stocks are not adjusted at this point.

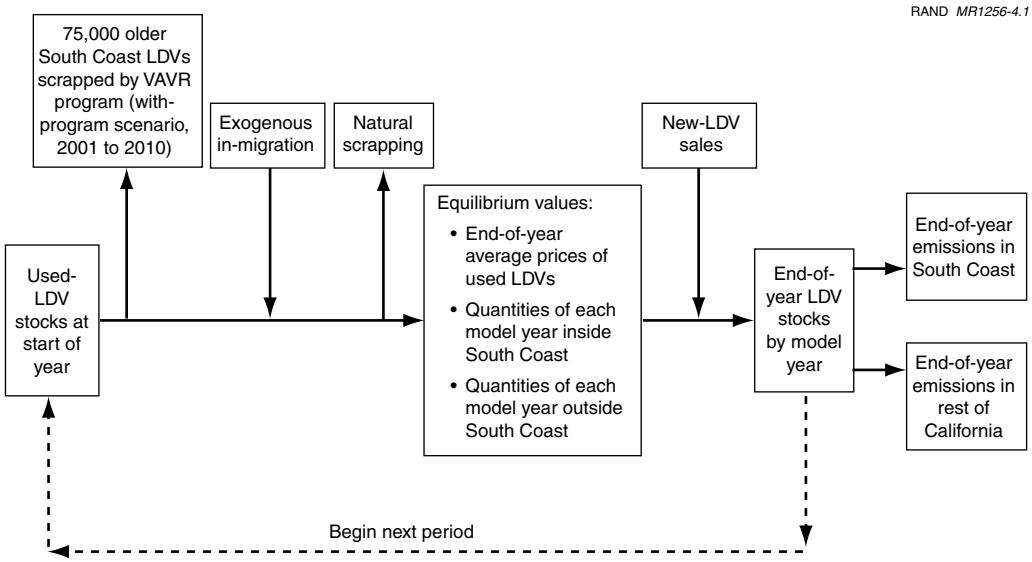

Figure 4.1—Overview of Calculation of Used-LDV Prices, LDV Quantities, and Emissions in Any Calendar Year

Next, vehicle stocks are updated to account for migration into the South Coast and the rest of California resulting from population growth. In particular, in the without-program run, stocks of vehicles of all vintages are increased by 1.5 percent each year in both the South Coast and the rest of California.[3] For the with-program scenario, the same numbers of LDVs of various vintages are added to the LDV stocks as are added in the without-program scenario. We refer to these increments in LDV stocks throughout the state as *exogenous* in-migration because they are determined outside the model.[4]

Next we decrease stocks of LDVs to represent *natural scrapping* of LDVs, by which we mean all vehicle retirements other than those effected by purchasing and scrapping LDVs through the VAVR program. Natural scrapping is projected in the without-program scenario using data from CARB on the fraction of currently operating LDVs of a given age that will continue to operate for at least one more year. More specifically, for each cohort of LDVs of a particular model year, we use the CARB data to predict how many will be retired in each successive calendar year for which the model is run. These values are used to represent levels of natural scrapping of each model year in each calendar year in the without-program run.

[3]This growth factor is chosen to be consistent with CARB's assumptions about growth in vehicle stocks and with recent data on new vehicle registrations in California.

[4]Exogenous in-migration contrasts with increments in South Coast LDV stocks due to migration of LDVs from the rest of California, which are effects of the program determined within the model.

Fewer LDVs will be scrapped naturally in any year if the VAVR program is implemented. This is because with the VAVR program in operation, some LDVs that would have been scrapped naturally in a given calendar year will have previously been scrapped through the VAVR program. Our adjustments to natural scrapping to represent the previous operation of the program are based on assumptions about the remaining lives of the LDVs that are scrapped through the program, as detailed in Section 5.

After the used-LDV stocks are adjusted to account for exogenous in-migration and natural scrapping, we then compute for each scenario *equilibrium prices* of used LDVs and *equilibrium quantities* of LDVs of each vintage inside and outside the South Coast. This is done using a supply and demand framework by

- constructing for the South Coast and the rest of California separate demand functions for all used LDVs aggregated over model years,
- specifying conditions for equilibrium across the two regions, and
- reallocating the stocks of California LDVs over the regions to satisfy an equilibrium condition.

The demand functions for each of the two regions are calibrated for 2001—the first year for which the model is run—using values of stocks of LDVs for each region in 2001 that accord with CARB projections. The equilibrium condition we typically employ is that average used-LDV prices are the same across the two regions in every year. In the with-program scenario, the South Coast gains LDVs through the reallocations because the retirement of South Coast LDVs by the program would—absent geographic reallocation of LDVs—tend to increase prices in the South Coast. Moving LDVs from outside the South Coast to inside the South Coast is thus required to equalize used-LDV prices. These movements of LDVs to the South Coast represent in-migration due to the program.

All prices are expressed in 1999 dollars; that is, they do not build in any effects of inflation after 1999. Equilibrium prices are determined on the basis of demand conditions in the current period and LDV stocks, which depend on events in previous years.[5] The calculations predict prices of used LDVs in the South Coast and the rest of California, which are assumed to be the same within each scenario for the end of each of a sequence of years beginning with 2001. The predicted price reported for a given calendar year and scenario is the average of the predicted

[5]LDVs are durable commodities that, once produced, last for more than one year. Thus, it is crucial to specify market conditions in any year based on an accurate reflection of quantities of LDVs that are carried over from earlier years. In contrast, prices can adjust freely in each year to accommodate current quantities of used-LDV stocks, new-LDV sales, demand conditions, etc. Thus, we compute equilibrium prices in any year based on market conditions in that year, which depend on several factors including stocks carried over from the previous year.

prices from the ends of the current and previous years. The effect of the program on used-LDV prices in any year is the predicted average price of used LDVs with the program minus the predicted average price without the program.

To calculate stocks of LDVs for the end of any year, a quantity of new LDVs is added to represent sales in that year. As a result of the VAVR program, new-LDV sales will increase in California to the extent that the program increases used-LDV prices, because new LDVs are substitutes for used LDVs. To determine the quantities of new-LDV sales with and without the program, reference levels of new-vehicle sales are first specified outside the model. The reference level for 2001 is estimated using historical data on new-LDV sales in California and levels for subsequent years based on a growth rate for demand of 1.5 percent per year. These reference levels are interpreted as the levels of new-LDV sales that would occur if price differences between used and new LDVs were constant over time. Changes in used-vehicle prices predicted by the model are then used to adjust the reference levels to predict actual levels of new-LDV sales. New-vehicle sales are assumed to rise as used-LDV prices increase because there is sufficient competition in California new-LDV markets to expect new-LDV prices to be determined largely by their production, transportation, selling, and other costs, which should be unaffected by the program; and the increase of used-LDV prices caused by the program would increase demand for new LDVs, which are substitutes for used LDVs. Higher used-LDV prices in the with-program scenario than in the without-program scenario thus mean that new-LDV sales will be higher in the with-program scenario.

The effect of the program in any year on the quantity of used LDVs—or quantities of LDVs of any particular vintage or set of vintages—is defined analogously to its effect on prices, namely as the difference in any year between corresponding values in the with- and without-program scenarios.

Emissions levels are expressed, as in the SIP, in terms of daily tons of ROG plus NOx emitted from LDVs operating alternatively in the South Coast and in the rest of the California. End-of-year emissions levels are calculated from end-of-year LDV stocks using CARB estimates for the relevant calendar year of

- emissions rates, in grams per mile, of LDVs of each vintage, and
- miles driven per day of LDVs of each age.

The total vehicle miles driven by LDVs in any region in any year are assumed to be the same with or without the VAVR program in operation. More specifically, to calculate emissions in the with-program scenario in any year, we adjust miles-per-day figures for LDVs of each model year by the same proportion so that total miles driven per day are the same as in the without-program scenario for that year.

MAINTAINED ASSUMPTIONS, BASE CASE, AND SENSITIVITY ANALYSES

Several assumptions of the model are used in all simulation runs, except a few runs designed to gauge the importance of these assumptions. These "maintained assumptions" are detailed in the next section. Several other assumptions differ over successive runs because the empirical basis for them is far from definitive, and we want to assess the robustness of our estimates to changing them.

First, a set of *base-case* assumptions is specified. We chose assumptions that appeared reasonable given available information. In several instances, base-case values are chosen to err on the side of attributing lesser emissions benefits to the program. We devote substantial attention to presenting and interpreting results for the base case in order to understand various features of the model and to develop conceptual insights that provide general lessons about effects of large-scale, multi-year VAVR programs.

We then consider alternative values for six parameters to assess the sensitivity of the results to plausible changes in parameter values.[6] Sensitivity is assessed first by rerunning the simulations varying one parameter at a time over a range judged to span values that are plausible. Doing so

- aids understanding of the workings of the model,
- provides a means of assessing the reliability of the model, and
- is instructive about the importance of individual parameters in determining the degree of uncertainty about effects of the program.

Because we are uncertain about appropriate values of several parameters, however, varying one parameter at a time, as just described, does not provide a reliable indication of the full range of program effects that is plausible. Accordingly, we also consider the sensitivity of our predictions to changing multiple parameters jointly from their base-case values. More specifically, we construct alternative cases that lead to relatively large and relatively small effects of the program to develop what we refer to as "credible ranges" for these effects.

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[6]These parameters are the number of LDVs scrapped by the program each year, average remaining life of LDVs scrapped through the program, the elasticity of demand for new LDVs, the elasticity of demand for used LDVs, and the average prices of new and used LDVs in California in 1999.