2. MARKET EFFECTS OF THE PROGRAM: CONCEPTUAL ANALYSES

We seek to understand effects of the planned South Coast VAVR program on vehicle prices, the number and age distribution of vehicles operating in the South Coast, and ROG and NOx emissions in the South Coast over the course of several years. The goal is to generate predictions that reflect the potential ranges of effects and will be useful to policymakers. This section presents some conceptual (theoretical) analyses that provide a foundation for the subsequent quantitative analyses.

ROLE OF CONCEPTUAL ANALYSIS

In this section we use a series of economic models that incorporate principles of supply and demand. The analyses in this section:

- identify the kinds of factors that will determine the directions and sizes of various program effects,
- provide a logical framework for constructing and judging the appropriateness of our quantitative models, and
- establish two powerful implications of basic economic reasoning that prove invaluable in developing quantitative models.

LESSONS FROM A BASIC SUPPLY AND DEMAND ANALYSIS

The economic responses to the program of direct concern are market-level outcomes such as prices and quantities of LDVs operating in the South Coast. Analyzing price, migration, and emissions effects requires extensions of basic supply and demand models. In particular, the analysis must accommodate three types of complications: (a) vehicles of several ages (synonymously, “vintages” or “model years”); (b) vehicles operating both inside and outside the South Coast; and (c) time-dependent or dynamic effects.

The formal conceptual analyses presented here focus on effects of the program across LDVs of different vintages and over different regions. The models used for these conceptual analyses are much simpler than our quantitative models. In particular, the theoretical models distinguish between only two groups of vintages, older and newer LDVs, and explicitly consider only one time period.

In all of the conceptual analyses, we assume that LDVs not explicitly distinguished by type (i.e., age or region) are physically identical. The quantity measure is the number of LDVs in operation, not, for example, the number bought and sold during the time period. We use this definition of quantity because to understand price determination it is crucial to take into account all LDVs potentially available for sale.[1] For LDVs that are not bought and sold during the period of analysis, price is interpreted as the price a private buyer and a private seller would agree upon if a transaction were to take place.[2]

To set the stage, consider Figure 2.1, which pertains to the effects of the program if there were only one type of used LDV (all of which are physically identical), one region, and one time period. In the figure, quantity (the number of LDVs operating during the period) is measured on the horizontal axis. Price—the market value of each LDV in dollars per vehicle—is measured on the vertical axis. In this and subsequent figures, the superscripts *w/* and *w/o* denote with and without the VAVR program, respectively. The quantity of LDVs potentially operating in the region is predetermined by stocks of LDVs previously produced and carried over into the current period (i.e., all LDVs are used). The program reduces the supply of LDVs that can operate during the period by purchasing and destroying a fraction of them.

The equilibrium price with the program is the price that equates quantity demanded with the quantity of LDVs available after the program eliminates some number of LDVs from the stock. Given the downward sloping demand curve, the decrease in supply increases LDV prices (i.e., the price with the program exceeds the price without the program) and reduces the quantity of LDVs on the road by the number of LDVs scrapped through the program.

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[1]We are modeling price and quantity determination in a situation lacking opportunities for production—i.e., a period starts with a stock of (used) LDVs produced previously. In much more commonly analyzed situations of nondurable commodities—where quantities are determined by current-period production—the appropriate quantity concept is the number of units of the good that are produced and sold during the period.

[2]Owners who do not sell their vehicles may be thought of as both demanding and supplying their own vehicles.

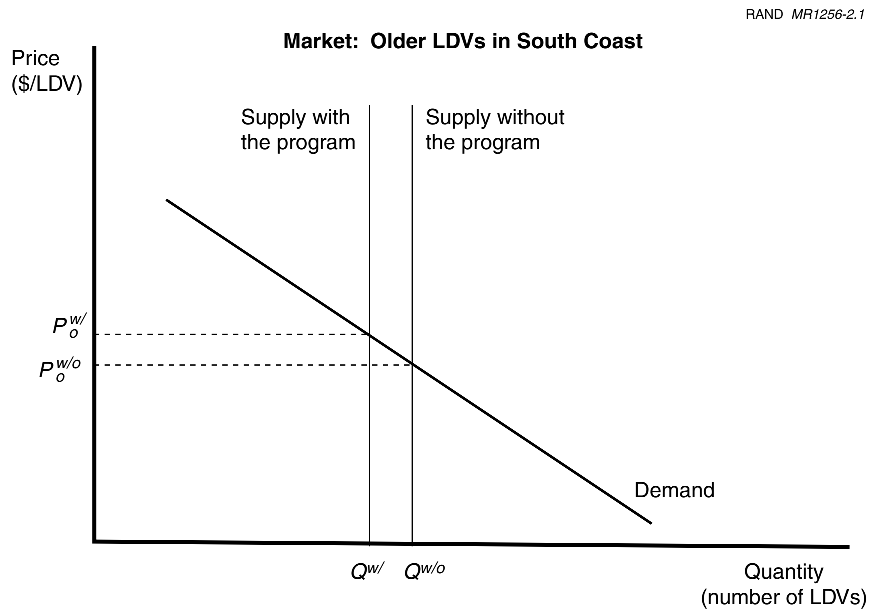

Figure 2.1—Effects of Program with Older LDVs Only, South Coast Closed to Migration

Even this extremely simple model points to two factors that are crucial to predicting effects of the program in the real world: the size of the program (number of LDVs scrapped) and the sensitivity of quantities demanded to price (the slope of the demand curve). Economists typically measure price sensitivity of demand in terms of "price elasticities of demand," specifically, the percentage change in quantity demanded divided by the percentage change in price that induces that change in quantity demanded.

INTERDEPENDENCE OF LDV MARKETS OVER VINTAGES

The model depicted in Figure 2.2 introduces a crucial complication: difference in LDV ages or *vintages*. The age of an LDV can be thought of as the current calendar year minus the model year (MY) of the vehicle. Here we assume for simplicity that there are only two LDV vintages: "older LDVs" (those old enough to be eligible for scrapping through the program, i.e., at least 15 years old) and "newer LDVs." We continue to assume that there is only one region, "the South Coast." The interconnected markets for older and newer LDVs are depicted in the upper and lower panels of Figure 2.2, respectively. Each market is viewed as competitive—i.e., modeled in terms of supply and demand. The quantity of LDVs of each type in the absence of the program is again assumed to be fixed.

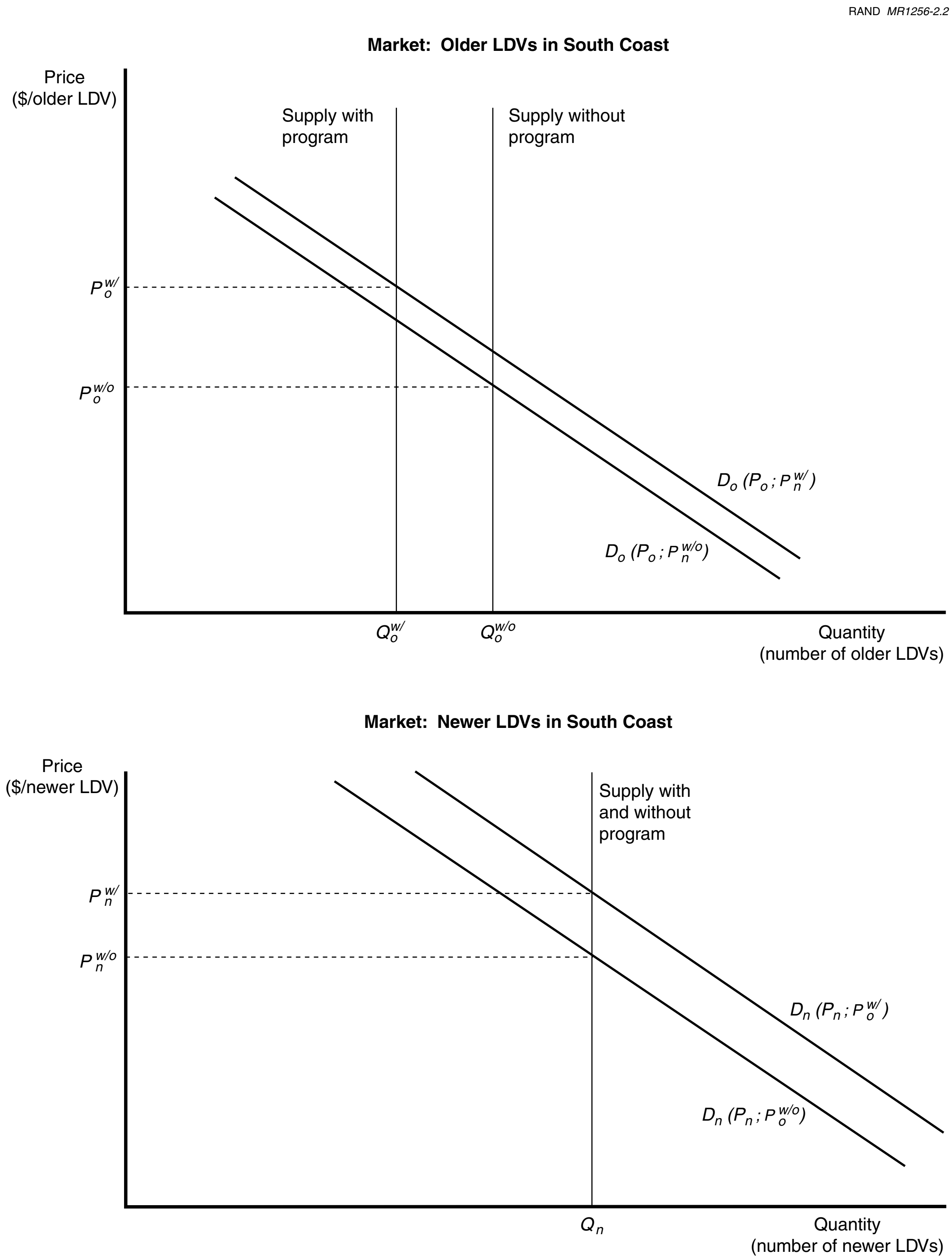

Figure 2.2—Effects of Program with Older and Newer LDVs, South Coast Closed to Migration

The markets are interconnected because older and newer LDVs are substitutes for each other, which means that the higher the price of one type of vehicle is, the greater will be the demand for the other type. More formally, as the price of one type of LDV increases, the demand curve for the other type shifts outward. For example, the higher the price of newer LDVs is, the greater is the quantity of older LDVs demanded at any older-LDV price.

What does this model add to our conceptual understanding of the effects of the VAVR program? The program decreases the fixed quantity of older LDVs by buying and scrapping them. This decrease leads to a tendency to increase the price of older vehicles, as illustrated in Figure 2.1. But, unlike the case of the simplest model, the process does not end there. In particular, the tendency for prices of older LDVs to rise also tends to increase the demand for newer LDVs—i.e., to shift out the demand curve in the lower panel. This increase in demand for newer LDVs will tend to increase the price of newer LDVs, which in turn will tend to increase the demand for older LDVs.

What is the overall—i.e., equilibrium—effect of these forces? Figure 2.2 depicts an equilibrium situation. Here the position of the higher demand curve for each vintage—the position of which is determined by the price of the other vintage—is consistent with equilibrium (the intersection of supply and demand curves) in the other market.

This model has the same conceptual predictions for *older* LDVs as the simpler model (Figure 2.1): The program reduces the quantity of older LDVs by the size of the program and increases the prices of LDVs old enough to be eligible for scrapping through the VAVR. The new, and crucial, lesson from the present model is, as depicted in the bottom panel of Figure 2.2, that the program will increase the prices of newer LDVs as well. This conclusion follows from the principle that increased prices for older vehicles increase the demand for newer vehicles because older and newer vehicles are substitutes.

How much should we expect the prices of older and newer LDVs to increase? Even the relatively simple model in Figure 2.2 suggests that this depends on several factors. In particular, holding constant the size of the program, the sizes of the price increases depend on the sensitivity of quantity demanded to price in each market (two "own-price elasticities of demand") and the extent to which a price increase in each market increases the demand for the other LDV type (a pair of "cross-price elasticities of demand").

WHAT VEHICLES WILL BE SOLD TO THE VAVR PROGRAM?

Of particular interest is the number of LDVs scrapped through the VAVR program in any year that will come from each vintage of LDVs aged 15 years or more in that year. A precise answer cannot be given because of lack of information about future program rules and about various characteristics of the LDV stock. The issue can be analyzed—and guidance developed for our quantitative analysis—as follows.

First, consider the fundamental motivations of LDV owners and enterprise operators. Because the program is voluntary, the owner of an LDV eligible for scrapping through the program will participate only if the price offered by an enterprise, often referred to as the "bounty," is viewed as attractive in comparison with the owner's alternative uses of the vehicle. For an owner who would keep an LDV if it is not sold to the program, the bounty, net of the inconvenience or transactions costs of selling the vehicle to the program, would have to exceed the value the owner places on the vehicle. For an owner who would sell an LDV even if it is not sold to the program, the bounty would have to exceed what the owner believes can be obtained from sale of the vehicle through channels other than the VAVR program, adjusted for any difference in transactions costs between selling to the program or to some other buyer.

The size of the bounty offered for any particular LDV will depend on how much money the enterprise operator expects to obtain by selling the resulting emissions credits to the state. The value of credits is yet to be determined, but it can be expected that the bounties offered for an eligible LDV will be roughly proportional to the emissions credits that would be generated by scrapping that vehicle.[3] As illustrated in Figure 1.2, this value varies across LDVs of different ages. With prices established for emissions credits, the value to enterprises of attracting LDVs into the program should be higher for model years that generate more credits.

In any year of program operation, the age distribution of LDVs that will be sold to the program depends on the following factors:

- the bounty offered for LDVs of each model year during that calendar year,[4]
- the number of LDVs of each model year that are eligible for scrapping (or are able to evade enforcement efforts to prevent scrapping out of compliance with the program rules) in that calendar year, and
- for each program-eligible model year, the fraction of LDVs for which the bounty offered is more attractive to their owners than the available alternatives.

The considerable increase in emissions credits with the age of vehicle over a broad range of ages (see Figure 1.2) suggests that vehicles that are scrapped through the VAVR program will disproportionately be particularly old LDVs.

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[3]The maximum value of an LDV to an enterprise is the value of the emissions credits available for scrapping that LDV plus the salvage value of the crushed or shredded vehicle, minus the transactions costs required, such as inspecting the LDV, either destroying the vehicle or arranging for someone else to destroy it, and doing the required paperwork.

[4]With competition among enterprises for LDVs to scrap through the VAVR program, the bounty for a vehicle will equal its value to enterprises.

THE PROGRAM WILL INCREASE PRICES OF ALL VINTAGES BY SIMILAR DOLLAR AMOUNTS

Even in the model depicted in Figure 2.2 with only two LDV vintages, price effects depend on own-price elasticities of demand for LDVs of each of the two vintages and the two cross-price elasticities of demand between the vintages.

In the quantitative model, we distinguish more than 20 vintages in order to take account of differing projected emissions rates by age, and we predict emissions levels in each year from 2001 through 2020. Developing quantitative models with 20 vintages based on separate own-price elasticities for each vintage and separate cross-price elasticities for each pair of vintages would involve roughly 400 demand parameters.[5] Doing so would be unwise because of the extreme complexity of the model and the likelihood of major inaccuracies.

Fortunately, economic reasoning suggests that introducing such complexity is unnecessary, even if it were possible. In particular, basic requirements for market equilibrium suggest that *the program will increase prices of all vintages by the same dollar amount*. This condition is employed in our quantitative analyses. It is important, then, to understand its basis and to appreciate that the reasoning is much more general than the case of only two vintages depicted in Figure 2.2, and that it also applies even if there is more than one geographic region.

The prediction follows from conditions required for LDV markets to be in equilibrium. First consider what determines the difference in price between *any* two vintages of LDVs in the absence of a VAVR program. This price difference depends on two fundamental factors: (a) the physical differences between the two LDV vintages, such as performance, appearance, maintenance costs, and expected remaining life; and (b) the dollar value that prospective buyers of these two vintages place on these physical differences. In any market equilibrium, the difference in price between any two vintages must equal the dollar value the relevant potential buyers place on those physical differences. If, for example, the price difference between older and newer LDVs is less than the dollar value consumers place on their physical differences, then buyers will view newer LDVs as a bargain. But attempts to take advantage of such bargains by selling older LDVs to buy newer ones would increase the price of newer LDVs and decrease the price of older LDVs until there were no such potential bargain. In sum, prices cannot be in equilibrium across *any pair* of vintages unless the price difference reflects consumer valuations of their physical differences.

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[5] Let N denote the number of vintages distinguished. This detailed modeling approach would involve N own-price elasticities and N(N-1) cross-price elasticities.

How does the existence of the VAVR enter into this analysis? The operation of the VAVR would change the sizes of price differences across any pair of vintages only to the extent that the program induces changes in the following factors:

- differences across pairs of vintages in the average desirability of the physical attributes of LDVs of those vintages,
- dollar values that consumers assign to such differences in the average desirability of physical attributes, and
- the groups of consumers owning or competing to buy LDVs of given vintages.

The VAVR program could affect all of these factors to some degree. However, the approximation errors involved in employing the assumption of equal price effects of the program on all vintages of LDVs appear to be minor, and the sensitivity analyses we performed appear very likely to swamp in importance these approximation errors. Consider, in turn, the potential importance of the three factors enumerated just above.

First, in the real world, the physical attributes of LDVs vary within a vintage, and the prices of interest for analytic purposes are average prices for each vintage. Would the VAVR program be expected to change the distribution of physical characteristics within a vintage in a way that would alter the average desirability of existing LDVs of that vintage? Substantial changes in average desirability would require that both (a) LDVs of a given vintage that are scrapped by the program are substantially different in terms of average physical desirability than those not scrapped by the program, and (b) the number of LDVs of a vintage that are scrapped is substantial relative to the overall number of such LDVs. The extent to which (a) occurs depends on program rules. As summarized in Section 1, under current rules, LDVs scrapped through the program must be in reasonably good condition. As discussed earlier in this section, the program should be expected to attract and destroy—from among those LDVs that are eligible given their physical conditions—LDVs that are of relatively low value to their owners. Thus, we expect that the program will tend to attract and scrap LDVs that are neither especially desirable nor especially undesirable among LDVs of their vintage. It is unclear, then, even whether the average physical desirability of LDVs of any age-eligible vintage would increase or decrease due to scrapping LDVs through the VAVR program. Moreover, regarding (b), the number of LDVs planned for scrapping through the VAVR program is a small fraction of the number of age-eligible LDVs in the stock. In particular, up to 75,000 LDVs are to be scrapped through the VAVR program annually. This maximum represents only 1.5 percent of the 4.90 million age-eligible LDVs in California in 1998 (see Table 3.1 below).[6] Thus, it seems unlikely that the program will

[6]We consider the annual size of the program relative to the size of vehicle stocks, rather than the cumulative program size, because the stock of age-eligible vehicles will be continuously

cause substantial changes in the average desirability of LDVs of any vintage, or, by implication, substantial changes in the difference across any pair of vintages in average physical desirability.[7]

Second, consumer valuations of any given differences in average physical characteristics across any pair of vintages—i.e., how much more a typical consumer would be willing to pay to purchase an LDV of a vintage that is viewed as more attractive than another—would change because of the VAVR program only if the program had substantial effects on real incomes. The program would have substantial impacts on real incomes only if price effects of the program were to decrease substantially the welfare of many consumers competing to buy LDVs of any given vintage. In light of the size of the price effects we estimate, the program should substantially decrease the welfare of only a small fraction of consumers, if any, in any market segment and thus should have only minor impacts on real incomes.

Third, the program could substantially alter average price differences across vintages if it were to change substantially the groups of consumers competing in the markets for particular vintages in a way that changes the average incomes of these groups. This is because consumers' willingness to pay to purchase LDVs depends on their ability to pay, which depend on their incomes. Because the program will reduce the sizes of stocks of age-eligible vehicles relative to those of newer LDVs, some consumers competing to buy LDVs will shift to newer vintages. This shift will affect the average incomes of consumers competing to buy LDVs of a particular vintage to the extent that consumers shifted into a market for newer LDVs have average incomes lower than those of consumers who would compete to buy vehicles in that market segment in the absence of the VAVR program. However, such changes in the groups of consumers competing to buy LDVs would affect all vintages similarly. Moreover, (as just described) the program will scrap only a small fraction of age-eligible vehicles. Thus, reallocation of consumers to newer vintages would have only minor effects on differences in average prices across vintages.

In sum, the assumption of equal price effects is grounded in economic reasoning and what is known about the program, and this assumption is likely to be a good approximation to the actual effects of the program.

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replenished over time as more become age-eligible. It is the size of the program relative to the size of vehicle stocks in all of California that will tend to determine the size of price effects, because, as we explain presently, prices of used LDVs will tend to be equalized across the state through migration of vehicles into the South Coast from the rest of California.

[7]The program would tend to increase the desirability of some vintages relative to others because LDVs of some vintages will command higher bounties from the VAVR program. We would not expect such an "option value" to have a substantial effect on the average desirability of vehicles of any vintage because, as just explained, only a small fraction of age-eligible LDVs can be sold to the program. Consequently, the probability of being able to exercise an option to sell to the program is quite small.

INTERDEPENDENCE OF VEHICLE MARKETS OVER SPACE

The model depicted in Figure 2.3 adds a different complication to the simple model in Figure 2.1: different geographic locations of LDVs. Here we assume that there is only one type (vintage) of LDV, older LDVs, and only two regions, inside and outside the South Coast.

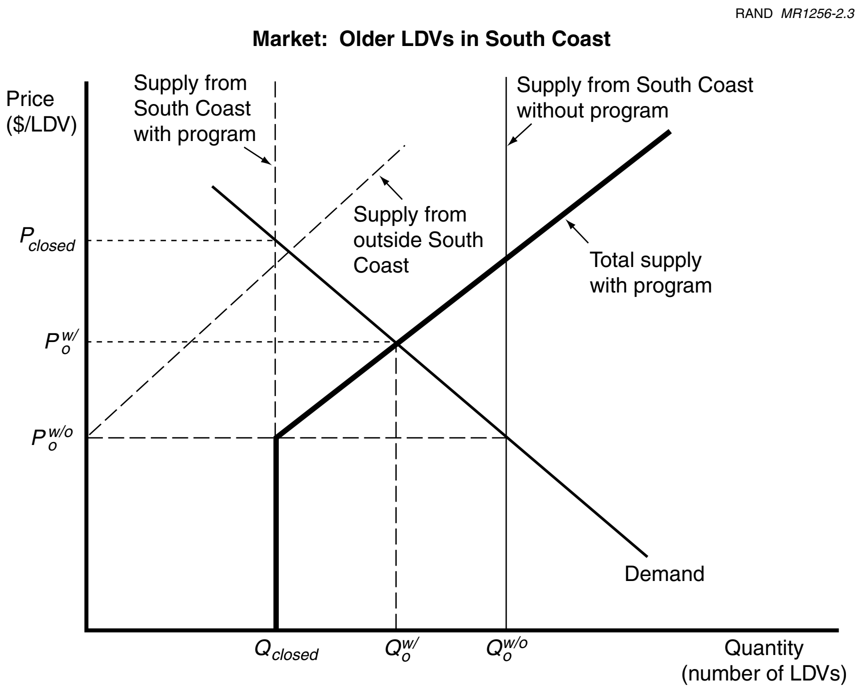

Figure 2.3—Effects of Program with Older LDVs Only, South Coast Open to Migration

Figure 2.3 depicts the market for older LDVs in the South Coast, with the number of LDVs operating in the South Coast measured on the horizontal axis and the average price (market value) of those LDVs measured on the vertical axis. As assumed in the model depicted by Figure 2.1, (a) the demand curve is for older LDVs in the South Coast, (b) the supply *from the South Coast* (i.e., the number of LDVs that begin the period in the region) is fixed, and (c) the program reduces that supply by the size of the program (number of LDVs scrapped).

The new feature of the model depicted in Figure 2.3 is the existence of another source of supply of (older) LDVs to the South Coast. These are older LDVs that start the period *outside* the South Coast but would, if economic incentives warrant, be brought into the South Coast for sale to consumers who would operate them there.[8] LDVs that start a period outside the South Coast but move into the South Coast because of the program are said to *in-migrate*.

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[8]This possibility is a concern often raised about the program.

As depicted in Figure 2.3, the supply of LDVs from outside the South Coast is assumed to be upward sloping, which means that the higher the price of LDVs in the South Coast, the higher would be the number of LDVs that would in-migrate. This assumption reflects the general ideas that owners of LDVs outside the South Coast would be willing to sell them to the highest bidder; the costs of selling vehicles increase with the distance between the seller and the buyer; and for more vehicles to migrate, they would have to come from greater distances.

The model depicted in Figure 2.3 formalizes the concept of in-migration. This very simple model provides two key predictions that pertain much more generally: (a) the program will reduce the number of LDVs operating in the South Coast by fewer than the number of LDVs purchased and scrapped by the program; and (b) the program will increase prices in the South Coast by less than would occur if in-migration were not possible. By adding to stocks of LDVs in the South Coast, in-migration attenuates the stock-reducing direct effect of a vehicle-scrapping program. The price-moderating effect of in-migration follows from the fundamental economic principle that larger supplies (in our case, LDV stocks) tend to reduce prices.

A key issue for our quantitative modeling is the conditions under which LDV markets will be in equilibrium across geographic areas or, equivalently, the conditions under which there will be no remaining tendencies for LDVs to migrate from one region to another. For example, should we expect LDVs to migrate if there are *any* substantial price differences over space, or are there important frictions that would prevent migration of vehicles to eliminate any substantial geographic price differences?

How nearly geographic reallocations of LDVs will equalize prices between the South Coast and the rest of California depends on

- the nature of the transactions that in combination would result in in-migration into the South Coast, and
- the extent to which transactions costs increase with geographic distance between buyers and sellers (e.g., costs of information or of transporting LDVs over distances).

Suppose, for example, that the requisite in-migration would be accomplished primarily by chains of transactions in which buyers of LDVs are typically nearer to the South Coast than sellers (so that transactions tend to move LDVs in the direction of the South Coast) but that buyers are not located very far away from sellers. Under these circumstances, approximate price equalization over space seems very likely because extra transactions costs due to geographic separation of buyers and sellers would be minor.

Available empirical information about spatial patterns of transactions and the relevant extra transactions costs is insufficient to construct supply curves corresponding to the one depicted in Figure 2.3. In our quantitative work, we emphasize the case where prices are equalized over space, because this equilibrium condition is simple and a useful approximation to reality. We also explore empirically how different the effects of the program might be because of equilibrium price differences over space by considering the extreme and implausible case where no in-migration occurs in response to the VAVR program.

VEHICLES OF ALL VINTAGES WILL MIGRATE INTO SOUTH COAST

Another key issue for constructing a quantitative model—and for assessing the emissions effects of the VAVR program—is the distribution of vintages that in-migrate because of the program. Analysis discussed presently suggests that the set of in-migrating LDVs will be composed of (approximately) the same fraction of the stock of each vintage outside the South Coast. This condition is imposed in our quantitative model. Thus, we explain its basis in a way that indicates that the reasoning is sufficiently general to apply to multiple vintages and geographic areas.

The incentive for owners or entrepreneurs to bring LDVs into the South Coast for sale is the prospect of obtaining higher prices or profits. The disincentive to migration is the potential *extra* transactions costs of selling vehicles over a distance relative to selling an LDV to a buyer who is located near a seller. Most obviously and tangibly, there are extra costs of transporting LDVs over longer distances. In addition, there can be additional costs of obtaining information and matching buyers and sellers located at some distance from each other.

In equilibrium, price differences for the same vintage at two different locations cannot exceed the extra transactions costs of selling in the higher-price area a vehicle that is currently located in the lower-price area. Assume that prices are equalized over regions before the program is implemented. The equilibrium requirement that prices rise by the same dollar amount for all vintages in response to the program implies that the incentive to migrate (the price premium between two locations) is the same for all vintages. Thus, the probability of a particular LDV migrating should be insensitive to its vintage, so we should expect similar proportions of LDVs of each vintage to migrate, unless the extra costs of selling over any distance differ considerably by vintage.

If distance-sensitive transactions costs differ by vintage, we should expect vintages with relatively low extra distance-sensitive transactions costs to account for a disproportionate share of in-migration. For newer vehicles, automobile dealers and wholesale auctions are likely to play an important role in reallocating LDVs over space.[9] In particular, in response to upward pressure on prices within the South Coast, dealers located in the South Coast can be expected to purchase

[9] For a discussion of automobile auctions, see Genesove (1991).

LDVs at auction for resale in the South Coast.[10] It is expected that these LDVs would be transported in groups rather than being driven (at a higher cost) individually into the South Coast. Because older LDVs are relatively unimportant to car dealers,[11] it is possible that older LDVs would more often migrate one at a time by being driven into the South Coast,[12] a form of in-migration that would involve higher time costs per LDV.[13] If price premiums become sufficiently high, however, businesses may emerge (or expand) that buy older LDVs outside the South Coast and transport several at a time for sale in the South Coast.

In sum, if distance-sensitive transactions costs do vary over vintages, migration of older vintages may involve higher distance-sensitive transactions costs than newer vintages. In our quantitative analysis, however, to be conservative in assessing program effectiveness, we assume that in-migration is composed of the same fraction of the stocks of each vintage outside the South Coast.[14]

WHAT DETERMINES EMISSIONS IMPACTS IN THE SOUTH COAST?

As in the SIP, we quantify emissions in terms of tons per day of ROG plus NOx emitted by LDVs. Total predicted LDV emissions in the South Coast on any day can be calculated from

- the number of LDVs of each vintage predicted to be operating in the South Coast,
- emissions rates for LDVs of each vintage (in grams of ROG plus NOx per mile), and
- miles driven per day by LDVs of each vintage.

Once the size and age composition of the LDV fleet in the South Coast are predicted, emissions predictions can be calculated.

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[10] Whether migrating vehicles would be brought into the South Coast before or after sale at auction is unclear, but is unimportant for our purposes.

[11] Genesove (1991, Table 1, p. 30) contains data from 1979 indicating that less than 3 percent of vehicles sold to consumers by new car dealers are more than 10 years old, and that the corresponding figure for used-car dealers is less than 10 percent.

[12] Conceptually, in-migration is defined as LDVs locating in the South Coast in the presence of the program that would have been located outside the South Coast in the absence of the program. Viewed from this general perspective, more subtle forms of in-migration would include owners who are moving out of the South Coast choosing to sell their LDVs before leaving to take advantage of higher prices, or people moving into the South Coast bringing LDVs with them who would have chosen not to do so in the absence of the VAVR program.

[13] The time costs per hour of owners of older LDVs may be lower, however, than the wage rates of drivers of multiple-LDV carriers.

[14] For example, if there are twice as many model-year 1998 as MY 1988 LDVs outside the South Coast, twice as many MY 1998 LDVs are assumed to in-migrate.

WHAT HAPPENS OVER TIME?

To this point, we have considered program effects during only a single period or year. The VAVR program is planned to operate for 10 consecutive years. In our quantitative analyses, we generate sequences of predictions over several years. We do this by using a series of one-year (static) supply and demand analyses that are linked over time through the quantities of LDVs that are predicted to exist at the end of a year and are thus carried over into the beginning of the following year. More specifically, three types of events affect the quantities of LDVs that begin a year:

- Natural vehicle scrapping or retirement by which LDVs are scrapped through normal channels, i.e., not through the VAVR program.
- New LDV purchases in California, which add to LDV stocks.
- Exogenous in-migration representing LDVs brought into the South Coast and the rest of California by people who move into the state.