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TRANSPORTATION ENERGY USE

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INTRODUCTION

This chapter forecasts transportation energy demand, for both the U.S. and California, for the next 20 years. Our guiding principle has been to concentrate our efforts on the most important segments of the market. We therefore provide detailed projections for gasoline (58% of California transportation energy Btu in 1988), jet fuel (17%), distillate (diesel) fuel (13%), and residual (marine bunker) fuel (10%). We ignore the remaining 2%—natural gas, aviation gaso-line, liquefied petroleum gas, lubricants, and electricity. Although we discuss prospects for the use of alternative fuels such as methanol and natural gas, we do not believe that these will be significant factors in the next 20 years. Table 1 gives an overview of transportation energy use in California and the U.S.

Our forecasting methodology is based on the principle that predictions should not depend on variables that are themselves difficult to predict; for example, a forecast that uses relative fuel prices as a key component is of little use if it is not possible to determine accurately the relative fuel prices. The resulting models are therefore quite simple: they depend only on such factors as demographics, time trends, and airplane scrappage patterns.[1] Although our projections do not explicitly model some factors, (e.g., the effects of tightened vehicle emission standards, aircraft noise restrictions, fuel prices, and congestion), we do take them into account to the extent that these factors were present, and changing, in data from our model-calibration periods.

Our predictions are that jet and diesel fuel demand will grow at slightly lower than current rates. Gasoline demand will grow at a much slower rate because vehicle ownership is becoming saturated. We are unable to forecast residual fuel demand, but it is irrelevant for energy policy since there will be a surplus of residual fuel in California for the foreseeable future. Overall, we predict that transportation petroleum demand will grow considerably more slowly than during the last 20 years in both California and the U.S. This suggests that rapid conversion to alternative fuels cannot be justified by demand pressures.

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[1] For expository purposes we do use forecast values of U.S. GNP in our jet fuel model, but the resulting forecasts are very similar to those from a simple time series model with a time trend. Except where otherwise noted, California data come from the *State Energy Data Report*, 1960–1988, published by the U.S. Department of Energy Energy, Information Administration. U.S. data come from Davis (1991), various editions of the *National Personal Transportation Survey*, and from *Highway Statistics*, published by the Federal Highway Administration.

TABLE 1 Transportation Energy Summary.

CALIFORNIA TRANSPORTATION ENERGY SUMMARY

California's transportation energy:
Petroleum is the source of over 99% of California's transportation energy. Transportation consumes 74% of the petroleum and 48% of the total energy used in the state.

California produces about 13% of the nation's total domestic oil.

We import half of the oil we use:
43% from Alaska and 4% from foreign sources.

75% of the oil is used in the transportation sector.

U.S. TRANSPORTATION ENERGY SUMMARY

Oil makes up 41.9% of U.S. energy.
Transportation uses 63.2% of that oil. Transportation, itself, gets 97.1% of its energy from oil. The transportation sector uses 27.3% of U.S. energy.

Of Total U.S. Vehicle Miles Traveled.
84% in autos and personal light trucks, 16% in commercial trucks.

Of Total U.S. Passenger Miles Traveled.
71% in autos, 14% in personal light trucks, 15% in commercial vehicles.

Total Freight Ton-Miles: 3,114 billion.
22% by truck, 28% by water, 19% by pipeline, 31% by rail.

Of All U.S. Transportation Energy.
40% used by cars, 18% used by light trucks, 14% used by other trucks, 3% used by off-highway vehicles, 9% used by airlines, 0.7% used by transit buses, 0.3% used by rail transit, 6% used by water freight, 4% used by pipelines, 2% used by rail freight.

WORLD TRANSPORTATION ENERGY COMPARISONS

Transportation uses more oil in the U.S.
In 1987 transportation accounted for 45% of total oil use in Europe and 38% in Japan. Public transit accounts for 22% of passenger miles in Japan, approximately 8% in Europe, and 1% in the U.S.

The U.S. had one third of all cars and buses in the world in 1988,
but this percentage is declining because cars per person is growing much faster in the rest of the world.

Gasoline prices are much lower in the U.S.
In 1989, one gallon of unleaded regular gas cost $3.41 in Japan, approximately $3.00 in Europe, and $.92 in the U.S. Nevertheless, new car fuel economy in the U.S. is similar to the rest of the world. Annual miles travelled per vehicle is about 85% of U.S. levels in Europe and 65% of U.S. levels in Japan.

SOURCES: *Economic Report of the Governor* (1990), pp. 43-45; Davis and Hu (1991), pp. xxiv, xxxi, 1-20; California Energy Commission (1992).

GASOLINE

Introduction

This section projects gasoline consumption through the year 2010. We begin by projecting vehicle miles traveled (VMT), then convert this to fuel consumption using estimated average fleet miles per gallon (MPG). The VMT projection is based entirely on demographic variables: size of population age cohorts, over time; the age-based pattern of drivers' licenses, over time; and the age-based pattern of yearly VMT. At each stage, the variables are split by sex. Thus the projection method depends upon age-based and sex-based driving patterns. We will discuss the data in more detail below, but the conclusion is that we expect them to be relatively reliable.

Once we have VMT projections, we convert VMT to fuel consumption via forecasts of MPG provided by two different sources: one assumes that CAFE (the congressionally mandated Corporate Average Fuel Economy standards) will remain unchanged; the other assumes that CAFE will rise from its current value of 27.5 MPG to 40 MPG by the year 2000. Our projections show the following results:

(1) U.S. population grows at 0.61% per year through the year 2010. California population grows at 1.18% per year. (2) U.S. VMT will grow at 1.94% per year through the year 2010. California VMT will grow at 2.62% per year. (3) If CAFE remains unchanged, fuel consumption will grow at 1.66% per year for the U.S., and 2.31% for California. (4) If CAFE standards are raised, fuel consumption will grow at 1.14% per year for the U.S., and 1.81% for California.

Fuel consumption grows faster in California than in the U.S., but the culprit is faster population growth, not faster travel growth; California is still receiving significant immigration. The large difference in fuel-economy standards produces relatively little difference in fuel consumption; the reason is that CAFE only affects new cars and it takes a long time for the existing fleet to turn over.

Basic Demographic Considerations

We begin by focusing on the remarkable changes in automobile availability that have occurred since World War II. In 1946 one might have spoken of the "family car" because there was approximately one car per household, and the family's many potential drivers competed for its use. But given the increase in personal income since then, and the high utility for personal mobility, families bought more and more vehicles until today we have approximately one vehicle for every potential driver. The rapid growth in the vehicle/population ratio meant that VMT, fuel consumption, and congestion all grew faster than the population.

Figure 1 shows the overall story: disproportionate growth of the vehicle population. The upper curve shows the size of the driving-age population. The lower curve shows the size of the personal-use vehicle fleet. Vehicles have been increasing 2.9 times faster than the population of potential drivers since 1960, and the number of licensed drivers has increased even faster.

Two demographic factors caused drivers' licenses to increase much faster than the population. First, a major fraction of the population, the baby-boomers, reached driving age during the 1960s and 1970s. Second, the enormous growth in women workers produced a disproportionate growth in women drivers. In 1947, women were only 27% of the total labor force; by 1988, they were 45% of the total labor force. But the age-transition of the baby-boomers has finished, and the growth in women's labor force participation has about reached its peak. Looking at the ratio of women workers to the total labor force, almost all the growth in this ratio occurred in the early period: it grew by 20% during the decade of the 1970s, but only 5% during the 1980s. And the U.S. Bureau of Labor Statistics predicts it will grow by only 2 percentage points during the 1990s (Fullerton, 1989). That is, the effects of these two demographic factors on the growth in demand for auto travel is about completed.

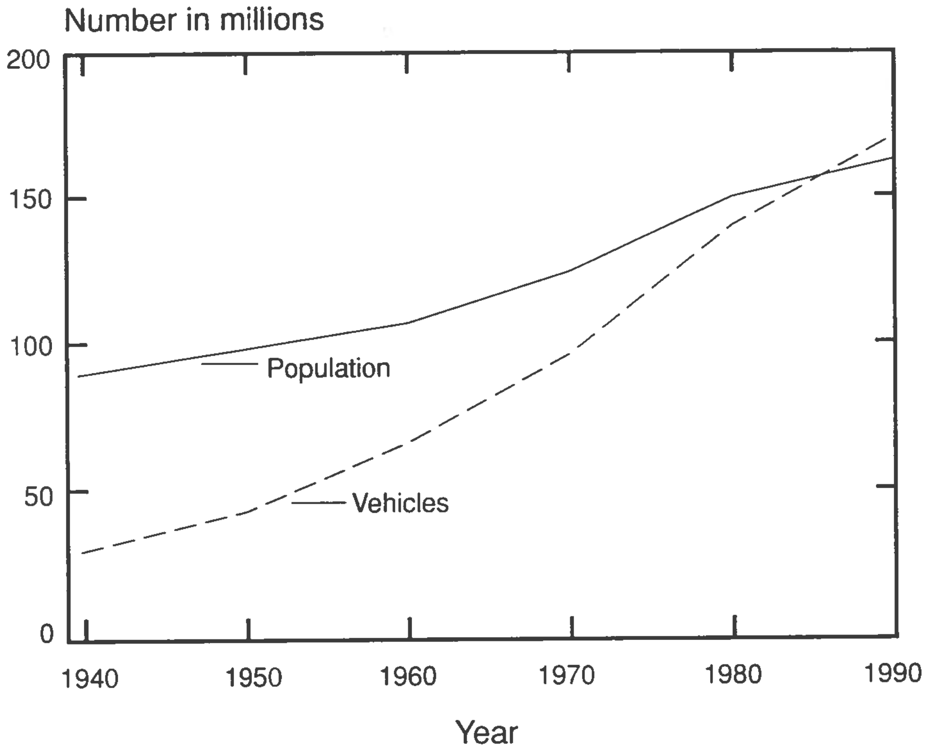

FIGURE 1 U.S. Driving Age Population and Personal Use Vehicles.

We have come through an era that produced remarkable increases in vehicle ownership and use. There will be no such changes in the future—we have nearly run these ratios to their limits. Vehicle ownership is close to saturation and the era of disproportionate growth is over.

Projecting the Number of Licensed Drivers

The key series required to project VMT is the number of licensed drivers. We project licenses for each age/sex cohort: age cohorts are in 5-year intervals, and men and women are projected separately; thus a typical cohort might be women age 40–44. The projection requires two things: first, the number of people in each age/sex cohort, up to the year 2010, and second, the proportion of each age/sex cohort that is licensed. Population figures come from the U.S. Bureau of the Census. We make our own forecast of the proportion of licensed drivers in each cohort.

The proportion of the driving age population that is licensed has been growing steadily for as long as we have had automobiles, and is now near the point where almost everyone is licensed. Of the entire U.S. population age 15 and older: 91% of men are licensed and 79% of women are licensed, which means 85% of all the population above age 15 is licensed. Thus, a projection of the future proportion of licensed drivers has little scope for uncertainty: we are already at 85% and the theoretical ceiling is below 100%, since we must exclude 15-year-olds and the very old.

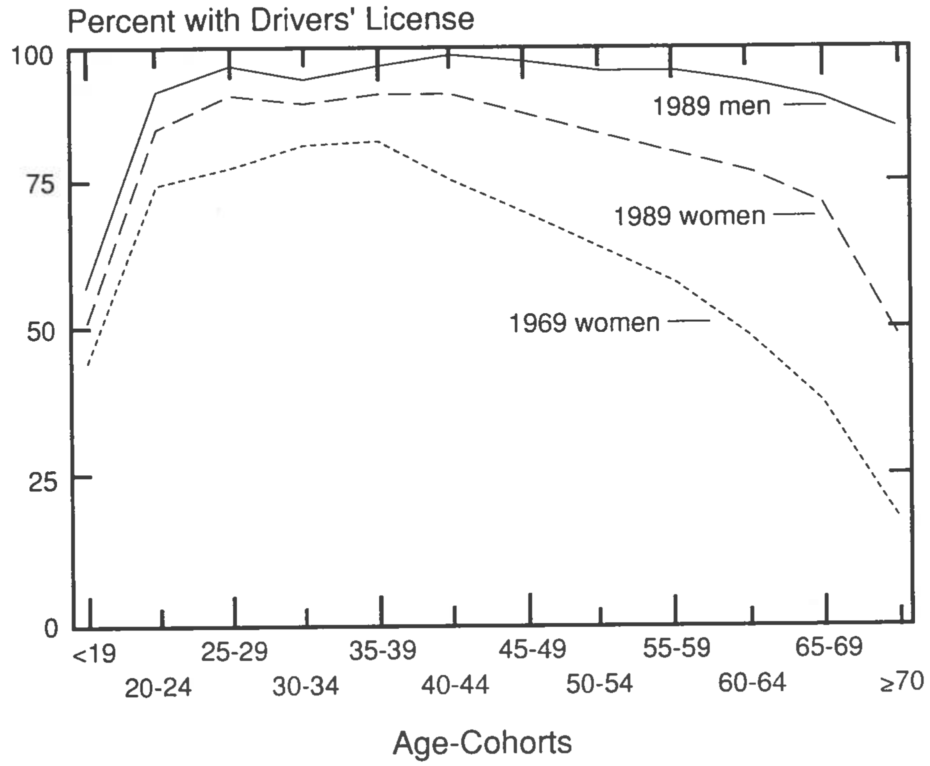

FIGURE 2 U.S. Drivers' Licenses as a Percentage of Driving Age Population.

Figure 2 shows the licensing pattern for the U.S. in 1969 and 1989. It shows near-saturation of male licensed drivers, as expected. Two curves are shown for women: the age distribution of licensing in 1969 and 1989. Comparing 1969 to 1989, we can see that the proportion of licensed women has grown remarkably—the female age distribution curve seems to be converging on a distribution similar to the male curve.

Table 2 give the details for projecting the licensing pattern to the year 2010. Part A of the table shows the existing age/sex licensing pattern.[2] Part B uses simple cohort aging to project licensing patterns for future years: we assume that once licensed, a person will remain licensed. Part C then fills in the missing triangle by assuming that the licensed proportion of each successive new generation will increase by 2% per 5-year period. Finally, to allow for the effect of extreme age on the licensing rate, we project changes in the 70+ cohort based on half the percentage difference between the 70+ cohort and the 65–69 cohort, 5 years earlier). We used a saturation limit of 100% for males and 95% for females.

Projecting VMT and Fuel-consumption

Table 3 shows the process for projecting U.S. total VMT and fuel consumption over the next 20 years. Part A shows projections of population size by age/sex cohorts. These projections come from U.S. Bureau of the Census Series P-17. The projection task is particularly simple in this case because they are projecting the

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[2] The 56.5% figure for young males applies to the entire 15-to-19-year-old cohort (the cohort used in the Census population data). The proportion of 16-to-19-year-olds who are licensed will be about 71%.

TABLE 2 Projection of Future Age-Pattern of Drivers' Licenses.
(percentage of licensed drivers by age cohorts)

	Males						*Females*				
	Known	*— Projected —*					*Known*	*— Projected —*			
Part A. Projection process begins with the known distribution.											
Age	*1990*	*1995*	*2000*	*2005*	*2010*	*Age*	*1990*	*1995*	*2000*	*2005*	*2010*
15–19	56.5					15–19	51.9				
20–24	92.7					20–24	86.4				
25–29	96.7					25–29	91.8				
30–34	94.4					30–34	90.3				
35–39	96.7					35–39	92.0				
40–44	99.0					40–44	91.9				
45–49	97.7					45–49	88.6				
50–54	96.0					50–54	84.8				
55–59	96.0					55–59	81.9				
60–64	94.2					60–64	78.3				
65–69	91.5					65–69	72.8				
70–85+	86.2					70–85+	49.9				
Part B. These tables show the effect of simple cohort-aging.											
15–19	56.5					15–19	51.9				
20–24	92.7	57				20–24	86.4	52			
25–29	96.7	93	57			25–29	91.8	86	52		
30–34	94.4	97	93	57		30–34	90.3	92	86	52	
35–39	96.7	94	97	93	57	35–39	92.0	90	92	86	52
40–44	99.0	97	94	97	93	40–44	91.9	92	90	92	86
45–49	97.7	99	97	94	97	45–49	88.6	92	92	90	92
50–54	96.0	98	99	97	94	50–54	84.8	89	92	92	90
55–59	96.0	96	98	99	97	55–59	81.9	85	89	92	92
60–64	94.2	96	96	98	99	60–64	78.3	82	85	89	92
65–69	91.5	94	96	96	98	65–69	72.8	78	82	85	89
70–85+	86.2	92	94	96	96	70–85+	49.9	73	78	82	85
Part C. Next, early age cohorts grow at 2% per five-year period, 70–85+ age cohort at half the difference between prior 70–85+ cohort and prior 65–69 cohort.											
15–19	56.5	58	59	60	61	15–19	51.9	53	54	55	56
20–24	92.7	95	96	98	100	20–24	86.4	88	90	92	94
25–29	96.7	99	100	100	100	25–29	91.8	94	95	95	95
30–34	94.4	97	99	100	100	30–34	90.3	92	94	95	95
35–39	96.7	94	97	99	100	35–39	92.0	90	92	94	95
40–44	99.0	97	94	97	99	40–44	91.9	92	90	92	94
45–49	97.7	99	97	94	97	45–49	88.6	92	92	90	92
50–54	96.0	98	99	97	94	50–54	84.8	89	92	92	90
55–59	96.0	96	98	99	97	55–59	81.9	85	89	92	92
60–64	94.2	96	96	98	99	60–64	78.3	82	85	89	92
65–69	91.5	94	96	96	98	65–69	72.8	78	82	85	89
70–85+	86.2	89	90	91	91	70–85+	49.9	61	64	66	67

population 15 and older, over the next 20 years: essentially all these people have already been born. They do have to project and add in immigration, but the effect on the total U.S. population will not be large because at this stage in our history growth comes mostly from births rather than immigration.

Part B repeats the drivers' license projections developed in Table 2. Part C shows the amount of driving by a *typical person* in each age/sex cohort. The figures come from the preliminary tabulations of the 1990

TABLE 3 Process for Projecting VMT & Fuel Consumption.

Males						*Females*					
Part A. Population projections from U.S. Census Series P-17, by age cohort (in thousands)											
Age	*1990*	*1995*	*2000*	*2005*	*2010*	*Age*	*1990*	*1995*	*2000*	*2005*	*2010*
15–19	8865	8944	9735	9928	9605	15–19	8516	8585	9340	9512	9198
20–24	9244	8647	8706	9470	9648	20–24	9238	8629	8688	9432	9599
25–29	10708	9416	8808	8847	9595	25–29	10678	9424	8804	8850	9590
30–34	11195	10987	9680	9070	9108	30–34	11147	10937	9661	9034	9082
35–39	10026	11092	10882	9599	8991	35–39	10146	11105	10890	9627	9002
40–44	8691	9944	10995	10792	9527	40–44	8964	10125	11074	10863	9612
45–49	6809	8580	9822	10871	10677	45–49	7132	8903	10057	11005	10799
50–54	5590	6705	8467	9706	10748	50–54	5948	7102	8870	10029	10976
55–59	5070	5386	6478	8195	9403	55–59	5552	5842	6981	8722	9856
60–64	5032	4763	5078	6126	7770	60–64	5708	5333	5620	6720	8401
65–69	4655	4603	4382	4705	5695	65–69	5596	5453	5109	5402	6467
70–85+	8197	9199	9892	10202	10677	70–85+	13110	14508	15499	15966	16523
Part B. Percentage of each age cohort that have drivers' licenses											
15–19	56.5	58	59	60	61	15–19	51.9	53	54	55	56
20–24	92.7	95	96	98	100	20–24	86.4	88	90	92	94
25–29	96.7	99	100	100	100	25–29	91.8	94	95	95	95
30–34	94.4	97	99	100	100	30–34	90.3	92	94	95	95
35–39	96.7	94	97	99	100	35–39	92.0	90	92	94	95
40–44	99.0	97	94	97	99	40–44	91.9	92	90	92	94
45–49	97.7	99	97	94	97	45–49	88.6	92	92	90	92
50–54	96.0	98	99	97	94	50–54	84.8	89	92	92	90
55–59	96.0	96	98	99	97	55–59	81.9	85	89	92	92
60–64	94.2	96	96	98	99	60–64	78.3	82	85	89	92
65–69	91.5	94	96	96	98	65–69	72.8	78	82	85	89
70–85+	86.2	89	90	91	91	70–85+	49.9	61	64	66	67
Part C. Expected number of miles per year driven by a driver of a given age											
15–19	9543	10030	10541	11079	11644	15–19	7387	7764	8160	8576	9013
20–24	16784	17640	18540	19485	20479	20–24	11807	12409	13042	13707	14406
25–29	18517	19461	20454	21497	22593	25–29	11191	11762	12362	12992	13655
30–34	19592	20591	21641	22745	23905	30–34	10785	11335	11913	12521	13159
35–39	19298	20282	21317	22404	23546	35–39	11437	12020	12633	13278	13955
40–44	19396	20385	21425	22518	23666	40–44	11021	11583	12174	12795	13447
45–49	18836	19797	20806	21867	22983	45–49	9956	10464	10997	11558	12148
50–54	18081	19003	19972	20991	22061	50–54	8693	9136	9602	10092	10607
55–59	17027	17895	18808	19767	20775	55–59	7681	8073	8484	8917	9372
60–64	13308	13987	14700	15450	16238	60–64	6706	7048	7407	7785	8182
65–69	10432	10964	11523	12111	12729	65–69	5885	6185	6501	6832	7181
70–85+	8298	8721	9166	9633	10125	70–85+	3976	4179	4392	4616	4851

Nationwide Personal Transportation Survey. We assume that the VMT figures for each cohort will grow at 1% per year as they have in recent years.

Part D shows the *total VMT* per age/sex cohort, in billions of miles per year. It is the product of the first three matrices, A × B × C: (number of people per cohort) × (proportion of the cohort that is licensed) × (VMT per driver of given age/sex characteristics). Part E gives the aggregate totals by forecast year.

TABLE 3 (continued)

Part D. Expected total VMT by all the drivers in a given age cohort (in billions of miles). Calculated as (population) × (driver's license ratios) × (VMT/driver's license) = total VMT.

Males						*Females*					
Age	*1990*	*1995*	*2000*	*2005*	*2010*	*Age*	*1990*	*1995*	*2000*	*2005*	*2010*
15–19	48	52	60	66	68	15–19	33	35	41	45	47
20–24	144	144	156	182	198	20–24	94	94	102	119	129
25–29	192	181	180	190	217	25–29	110	104	103	109	124
30–34	207	219	207	206	218	30–34	109	114	108	107	114
35–39	187	212	224	212	212	35–39	107	121	126	120	119
40–44	167	196	222	235	222	40–44	91	108	122	128	121
45–49	125	168	198	224	237	45–49	63	86	102	115	120
50–54	97	124	167	197	224	50–54	44	57	78	93	105
55–59	83	93	119	160	189	55–59	35	40	52	71	85
60–64	63	64	72	92	125	60–64	30	31	35	46	63
65–69	44	48	48	55	71	65–69	24	26	27	31	41
70–85+	59	71	82	90	98	70–85	26	37	44	49	54
Total	1,416	1,572	1,735	1,910	2,079	Total	764	853	941	1,033	1,123

Part E. Total VMT

	1990	*1995*	*2000*	*2005*	*2010*
Male + Female	2,180	2,425	2,676	2,943	3,202

Part F. Average MPG of entire vehicle fleet

	1990	*1995*	*2000*	*2005*	*2010*
CalTrans Estimate	16.4	16.6	16.9	17.1	17.3
Santini Estimate	16.4	17.1	17.7	18.5	19.2

Part G. Fuel consumption by total vehicle fleet (estimated total VMT divided by estimated fleet MPG = gallons consumed)

	1990	*1995*	*2000*	*2005*	*2010*
Using Cal Trans MPG	133	146	159	172	185
Using Santini MPG	133	142	151	159	167

Part H. Comparisons: Results for year 2010 versus year 1990

	2010/1990	*Annual Growth Rate (percentage)*
Total Population	1.13	0.61
Driving Age Population	1.18	0.82
No. of Drivers' Licenses	1.25	1.12
Total VMT	1.47	1.94
Fuel Use, CalTrans	1.39	1.66
Fuel Use, Santini	1.25	1.14

To convert VMT into fuel-consumption, we need a fuel-efficiency forecast. We use two alternative forecasts, one by Daniel Santini at the U.S. Department of Energy's Argonne National Laboratory, and one by the California Department of Transportation (Lynch and Lee, 1989).

The CalTrans projections assume stable fuel prices and no change in the federally mandated CAFE (Corporate Average Fuel Efficiency) standards that govern fuel efficiency. Despite this, the CalTrans model projects a 13% increase in average MPG of the auto fleet by the year 2010 because older autos are gradually being replaced by new ones. Similarly, CalTrans projects an 8% increase in the average MPG of light trucks by 2010. Heavy truck fuel efficiency is assumed to remain constant.[3]

The Santini projections were prepared specifically to examine the impacts of the Bryan bill now in Congress: it would mandate that CAFE be raised to 40 MPG by the year 2000, from the current level of 27.5 MPG. Santini assumes that these mandated CAFE standards are implemented. However, to the extent that the resultant new cars are less desirable to consumers—less powerful, smaller, more expensive—it will influence the *number* of new cars that are bought. Thus fleet turnover will be strongly affected because some people will keep their old cars longer. Santini incorporates these turnover effects and computes the expected average fleet MPG over time. Since 76% of light trucks are used for personal travel, he includes these in his projections as well. He estimates the fuel efficiency of the combined personal truck and auto fleet as 19.7 MPG in 1990 and projects that this will rise to 26.0 MPG in 2010, a 32% improvement. (These are actual, on the road, MPG figures.)

Part F shows the resultant fuel efficiencies for the total vehicle fleet (personal-use vehicles and heavy trucks), using both the CalTrans and the Santini projections. The small difference between the two projections, 19.2 versus 17.3 MPG in 2010, may seem surprising. The explanation is simply that cars are long-lived goods; it takes a very long time for the efficient new cars to replace all of the existing fleet.

Part G multiplies the fuel-efficiency projections from matrix F by the VMT projections of matrix E, to produce forecasts of total fuel consumption for the United States for the period 1990 to 2010.

Finally, Part H summarizes all the results, and puts them into perspective by comparing the changes in the important basic constituents. Over the next 20 years, our United States projections show:

(1) Drivers' licenses will grow slightly faster than the population because the transition to a fully licensed population is still going on; but that transition is nearly finished: compare the 1.12% projection with the 3.03% annual growth rate from 1950 through 1980. (2) VMT will grow at 1.94% per year, compared to the 4.62% annual growth rate for the 1950 to 1980 period. (3) Gasoline consumption will grow in the 1.14 to 1.66% range, depending upon the assumptions one makes about CAFE. Compare this to the 4.7% growth rate from 1950 through 1973.

That is, we expect a very substantial drop in the growth trends that have caused so much concern to environmentalists and conservationists.

We follow exactly the same process to make projections for California, but use California's own population structure and driving patterns. Table 4 shows the results and compares them to the U.S. projections. It is important to notice that California's faster growth of VMT and fuel consumption stem from its faster population growth.

Possible Influence of Public Transportation

Might increased use of public transit affect these projections? The answer is "no." Furthermore, this gloomy statement can be made with a high degree of certainty. Two main factors lead to the conclusion, and they are independent of each other; either is sufficient, by itself. First, there is little difference in energy efficiency between autos and public transit. Second, there are strong reasons to believe that it is impossible to lure a significant number of drivers onto transit.

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[3] Fuel costs are a significant proportion of operating costs for commercial trucks (in contrast to personal vehicles), hence commercial truckers have had very strong incentives to improve fuel efficiency since the first OPEC oil crises in 1973. CalTrans assumes that there is no room for further significant increases in the fuel efficiency of heavy trucks.

TABLE 4 Comparison: United States vs California.

	United States			California		
	1990	*2010*	*Annual Growth Rate*	*1990*	*2010*	*Annual Growth Rate*
Total Population (millions)	250	282	0.61	29.6	37.4	1.18
Driving Age Population (millions)	196	231	0.82	22.6	30.3	1.26
No. of Drivers' Licenses (millions)	167	208	1.12	19.5	28.0	1.83
Total VMT (billions)	2,180	3,200	1.94	262	439	2.62
Fuel Use, CalTrans (billion gallons)	133	185	1.66	14.6	23.1	2.31
Fuel Use, Santini (billion gallons)	133	167	1.14	14.6	21.0	1.81

Comparative Energy Efficiency. It may come as a surprise that there is little difference in Btu per passenger-mile between transit and automobiles. The differences in energy efficiency were never very large in the first place, and federal policy over the past 20 years has greatly reduced the gap. To begin with, federal CAFE standards have almost doubled auto fuel efficiency since 1973. In addition, as an unintended consequence of federal actions to increase transit patronage, the energy efficiency of the average transit vehicle has fallen by about 50%. (In order to make buses and trains more attractive—so as to lure drivers out of cars—federal funding encouraged conversion to air conditioned, heavier, more comfortable transit vehicles.) Table 5 shows the result of these changes. Autos, transit buses, and rail transit are now nearly equivalent. Even the airlines have made enormous gains in fuel efficiency.

TABLE 5 Energy Intensity of Passenger Modes.
(BTU per passenger-mile; operating energy only)

Year	*Autos*	*Buses*	*Rail Transit*	*Air Lines*
1973	5,562	2,597	2,460	8,919
1987	3,598	3,415	3,585	4,814

SOURCE: Davis and Hu (1991), pp. 2-25.

Caveats: The figures are for vehicles operating with average load factors. (1) Autos used for the journey to work have lower than average load factors, so auto energy-efficiency would be decreased about 50% for that portion of auto travel (the journey to work is about 30% of auto VMT). (2) The rail figure is the average between energy-efficient old rail systems such as the New York subways, and less efficient modern rail systems like BART and the Los Angeles Metro.

Conclusion: On balance there is little difference in energy efficiency between passenger modes. Hence, to save a substantial amount of energy, we must divert a very large proportion of auto users onto transit.

The Prospects for Increasing Transit Patronage. Since 1964 the federal Urban Mass Transportation Administration has spent about $60 billion trying to find some way of luring people out of cars. The money was easily available to pay for almost any conceivable experiment: subsidized fares, free fares, newer and more comfortable vehicles, more frequent vehicle schedules, free refreshments on board, nonstop express schedules, timed transfer systems, extended operating hours, computerized scheduling, radio communication, new kinds of schedules, special fares for special groups, free parking at transit stations, advertising, image improvement campaigns, etc. None of these experiments produced significant gains in transit patronage. The federal money managed to halt the long-term decline in patronage, but they could not increase it. Transit's share of total travel has declined by more than 51% from 1960 to 1980; from 12.6% of work trips down to 6.2% of work trips, and work trips are only about a third of total travel (Pisarski, 1987, p. 48).

Radical new policy measures such as substantial parking fees would increase transit usage for the tiny proportion of travel involved in commuting to large central business districts, but the effect on the overall volume of travel would be barely measurable.

Conclusion: It's very, very hard to lure people out of automobiles and onto transit. Even if it were possible (and there is *no* evidence in the literature to support this hope), we would still not save much energy because the energy efficiency of transit and autos are roughly similar.

JET FUEL

Introduction

Jet fuel is the second largest segment of California's transportation energy use, comprising 17% of transportation energy use in 1988. This figure is almost twice the U.S. national percentage (9%) due to California's large internal air market (the Los Angeles–San Francisco corridor) and California's position as a gateway for trans-Pacific flights. The traditional method for predicting commercial aviation energy demand is to multiply U.S. Federal Aviation Administration (FAA) forecasts for available seat miles (ASM) by some measure of fleet fuel efficiency. There are a number of problems with this approach:

(1) Although the FAA collects data for ASM and revenue passenger miles (RPM) for domestic flights, these data are not available for California. There is no reason to assume that California represents a constant proportion of the U.S. national figures over a 20-to-30-year period. The FAA national statistics exclude foreign flights, which, given the large number of Pacific Rim flights originating in California, makes them less useful for determining California's jet fuel consumption.

(2) The deregulation of domestic airline service in the early 1980s is a unique event whose impact cannot be captured well by models based on time series and economic variables. One important feature of deregulation is the growth of the hub-and-spoke system, which greatly increased the number of flights to and from the hub airports as well as load factors on these flights. Of course, deregulation also lowered fares for most travelers, which also increased demand. The net effect of these changes has been to increase jet fuel consumption while greatly increasing airline passenger-miles.

(3) From an energy policy perspective, we are not interested in RPM, just energy consumed. Therefore, it is better to forecast jet fuel consumption directly. Of course, for short-haul routes such as Los Angeles–San Francisco, planes compete with automobiles, and if one mode is more energy-efficient, then the cross-elasticity between the modes may be important. However, Table 5 shows that the energy efficiency of the two

modes was almost equal. Note that airliner efficiency increased twice as fast as other modes and should equal auto efficiency in the near future.

For these reasons, we have developed a direct forecasting model for jet fuel consumption, which depends on U.S. GNP and aircraft efficiency. This model is fully discussed in a later section. Although our projections include all nonmilitary uses of jet fuel, we will discuss only airline passenger demand. There are some cargo-only flights, but these are a tiny fraction of scheduled airline flights. Most air cargo is still carried in the baggage compartments of passenger airlines. Although it would be interesting to compare California domestic and international airline fuel demand, we were unable to find any data sources for quantifying this split. Unlike passenger automobile demand, per capita airline demand is not saturated and thus not limited by population growth.

Policy Issues

As opposed to the situation with automobiles, California has little scope for policy intervention to change jet fuel consumption. Federal law prohibits direct state regulation, and new federal laws have also limited adding new noise restrictions on airport operations. These noise restrictions force airlines to use newer, and generally more fuel-efficient, planes. In the longer run, California can attempt to block airport construction or expansion, which will eventually restrict the growth of jet fuel consumption. In the shorter run, the main restriction on airline growth is lack of capacity in the air traffic control system, which is managed by the federal government. One California airport, Orange County, also has binding constraints on the number of takeoffs as a result of noise control litigation.

Airports generate many costs and benefits, and these features will almost certainly dominate any fuel-consumption considerations. The main costs are noise and local traffic congestion. Balancing these are the obvious benefits to businesses of proximity to airports. To minimize jet fuel consumption, the best policy would be to limit small airports and build very large airports with large ground transport feeder networks. These large airports would allow the use of larger planes with higher load factors, which would in turn increase airline fuel efficiency. Of course, the direct and indirect costs of creating mega-airports will almost certainly swamp these fuel efficiency benefits.

The easiest way to increase airline fuel efficiency is to increase the number of passengers per plane, or load factor. The development of the hub-and-spoke system during the 1980s was primarily motivated by airlines' desires to increase load factors, and they succeeded in increasing them from 55% in the mid-1970s to 63% in 1989. Further expansion of hub-and-spoke systems is limited by congestion at key hub airports. Except for small hubs at San Francisco (United) and San Jose (American), geography dictates that California will be on the spokes of major national networks. Historically, San Francisco and Los Angeles have served as transfer and refueling stops for trans-Pacific air travel. While this will no doubt continue for the foreseeable future, new long-range aircraft will permit nonstop flights from the Far East to Midwestern hub cities. It is therefore not clear that California will be involved in all the projected growth in Pacific Rim air travel.

Since a substantial portion of California air travel is on the Los Angeles–San Francisco corridor, it is conceivable that an ultra high-speed rail link would substantially reduce jet fuel consumption. Since there have not been any serious proposals for such service, it is safe to say that such a system will not be operational during the 20-year forecasting period.

Forecasting Model

We base our forecasts for jet fuel consumption on a simple linear regression model relating the log of consumption to the log of fuel efficiency (measured as ASM per gallon of jet fuel averaged over the fleet; from Greene, 1990) and the log of U.S. GNP. Although the fuel efficiency variable might appear to be purely a technological variable, it also measures the speed of replacement of old jets. The decision to replace an old, fuel-inefficient jet is strongly determined by fuel prices and demand.

Our model accounts for the unique nature of the mid-1980s period, the result of airline deregulation, by excluding observations between 1984 and 1988 while calibrating our model. We are therefore assuming that the relationships between the variables in our model will be the same in the forecast period (1989-2010) as in 1970-1984. It is important to note that our calibration period includes wide variation in GNP, jet fuel consumption, jet efficiency, and fuel prices. Our model does not explicitly consider the effects of increasing fuel prices and incomes because these items are very difficult to determine. Of course, income is strongly related to GNP, which is included in our model.

Figure 3 shows jet fuel consumption for California and the U.S. California's higher rate of increase in the 1980s may be due to the increase in travel between the U.S. and the Pacific Rim. A large fraction of this travel involves jet fuel purchases in California. Comparison of figures 3 and 4 show that the number of passengers carried by domestic airlines has grown much faster than fuel consumption, due to the large increase in fleet fuel efficiency (Figure 5) over the period. Note that Figure 5 shows only the fuel efficiency due to the use of newer, more fuel-efficient aircraft. Another way to carry more passengers without using more fuel is to increase load factors, which is one of the main effects of airline deregulation. Our forecasting model for California is given by:

$$\log(\text{billion gallons of jet fuel}) = 13.6 - .8 \times \log \text{ of fuel efficiency} + .86 \times \text{BUSCYC} + .033 \times \text{Time}$$
$$(R^2 = .56)$$

where we have decomposed the logarithm of U.S. GNP into a time trend (Time) and a pure business cycle measure (BUSCYC), and fuel efficiency is ASM per gallon of jet fuel averaged over the U.S. jet fleet. This model is estimated over 1970 to 1984, and all of the coefficient estimates are significant at the 10% level. Holding efficiency and business cycle effects constant, the model predicts a 3% annual growth in California jet fuel demand. Holding GNP and time constant, a 1% increase in jet fleet fuel efficiency is associated with a 0.8% drop in jet fuel consumption.

A similar forecasting model for the U.S. is given by:

$$\log(\text{10 billion gallons of jet fuel}) = 9.1 - \log \text{ of fuel efficiency} + .45 \times \text{BUSCYC} + .047 \times \text{Time}$$
$$(R^2 = .70)$$

Relative to California, the U.S. model shows a higher time trend and slightly higher sensitivity to fuel efficiency. Assuming that U.S. GNP and fuel efficiency are known, both of these models give accurate predictions. For example, the forecast jet fuel consumption for the year 2000 will be between plus and minus 15% of the forecast value with 90% probability.

To determine future fuel consumption from this model, we need projections for the independent variables, U.S. GNP and jet fuel efficiency. For 1990-2000 we used the FAA forecasts for GNP, which are based on a consensus forecast from Wharton and DRI. For 2001-2010 we used our own projections derived from regressing the log of GNP on time. The resulting series has real GNP growing at a 2.6% rate over the period 1970-2010. For fuel efficiency, we used two scenarios from Greene (1990). The base case assumes no retrofitting (primarily new engines) and no "new generation" aircraft through 2010. Efficiency improvements still occur in the base case due to retirement of old, inefficient aircraft that are replaced by more efficient current models. The efficient scenario assumes new generation aircraft available in 2000 together with ac-

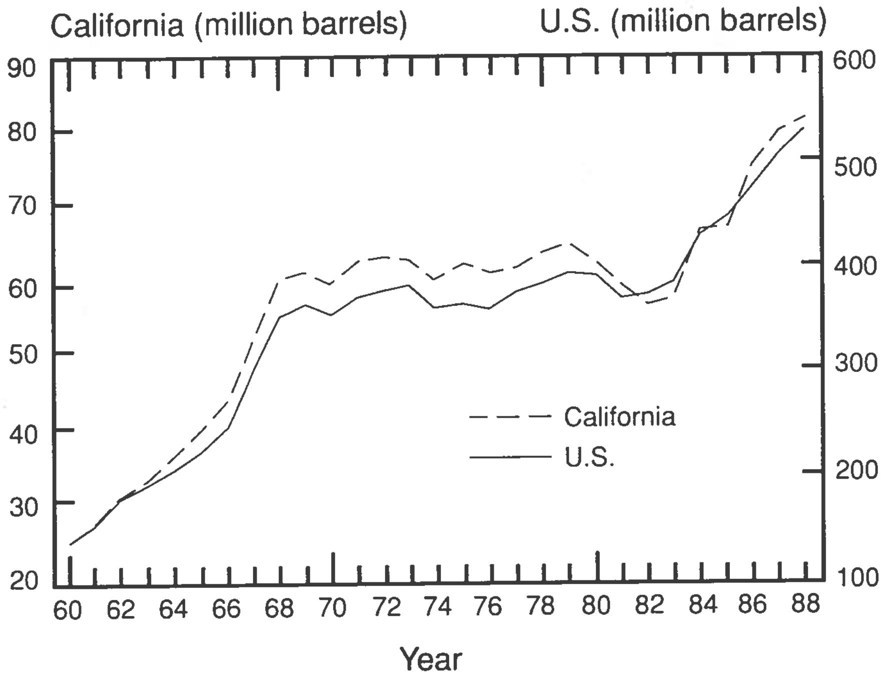

FIGURE 3 California and U.S. Annual Jet Fuel Consumption.

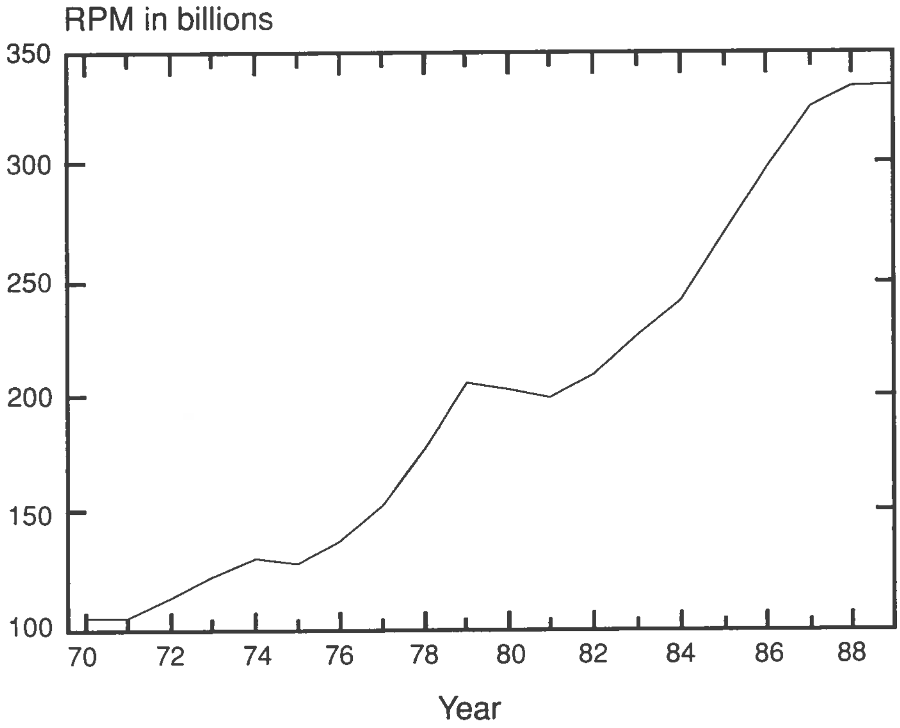

FIGURE 4 U.S. Airline Annual Revenue Passenger Miles.

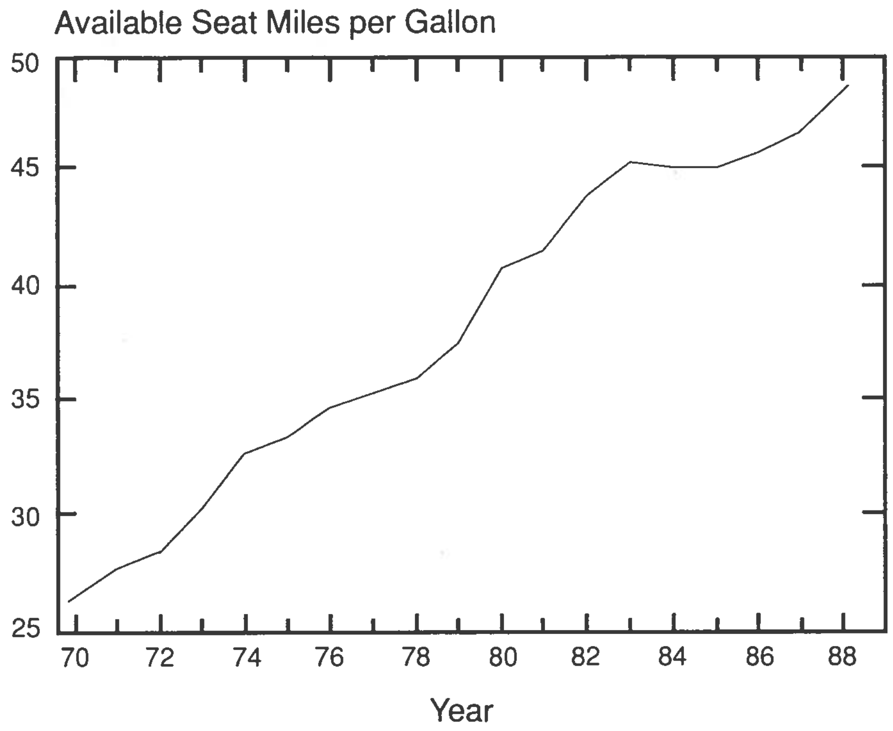

FIGURE 5 U.S. Jet Fleet Fuel Efficiency.

celerated scrappage and retrofitting of old planes. Greene views these cases as extremes bracketing the likely actual values.

To account for the unique 1984–1988 deregulation period, we produce forecasts for 1985–2010, and adjust all the figures upward so that the forecast equals the actual value for the last year of real data, 1988. This adjustment results in a 4% upward adjustment of our forecast values. This method treats the 1984–1988 increase in airline passenger and fuel demand as a unique event, caused by lower deregulated airfares and the switch to hub-and-spoke domestic networks. We are therefore assuming that for the next 20 years (1989–2010) the relationship between airline fuel demand, GNP, and airplane efficiency will follow the same patterns as in 1970–1984. Since the 1970–1984 period includes wide changes in business cycles and fuel prices, our forecasts should be valid as long as future variation in these variables is not much greater than in the 1970–1984 calibration period.

The projections (Figure 6) for the two different fuel efficiency scenarios do not differ significantly until 2000, with both showing a 25% increase in California jet fuel consumption over the 1988 base year. For the 2001–2010 period, however, the forecasts diverge. The base case shows a continued 20% increase, while the efficient case shows only a 5% increase. Which of these two scenarios is more likely depends largely on fuel prices. The faster jet fuel prices increase significantly, the more likely it is that jet fleet fuel efficiency will follow the efficient scenario. Figure 7 shows forecasts for U.S. jet fuel consumption using the same methods. These forecasts are similar to California's, except that U.S. jet fuel consumption is predicted to grow at a slightly faster rate.

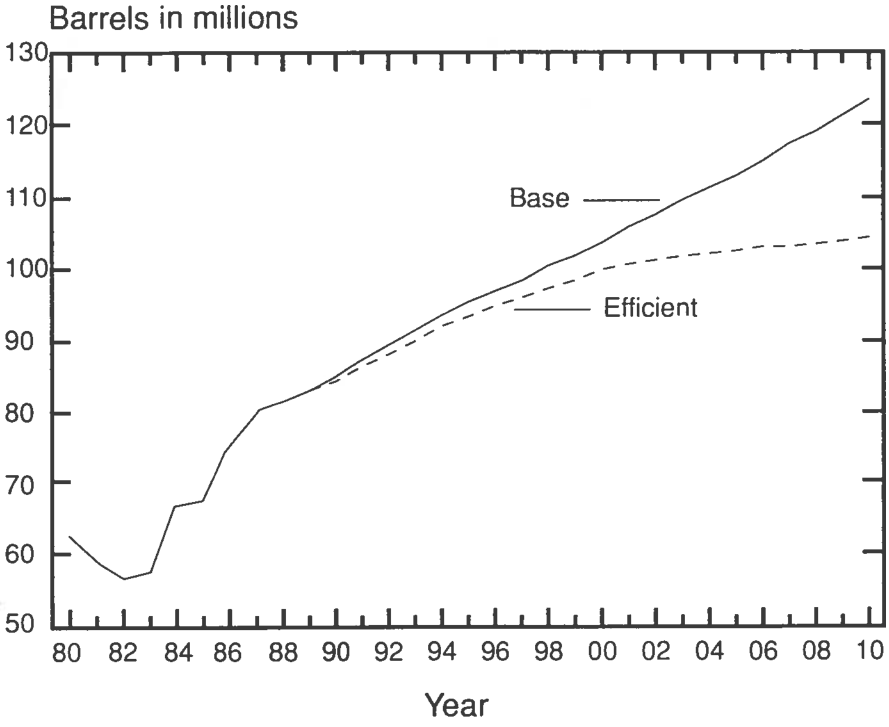

FIGURE 6 California Annual Jet Fuel Consumption Forecast.

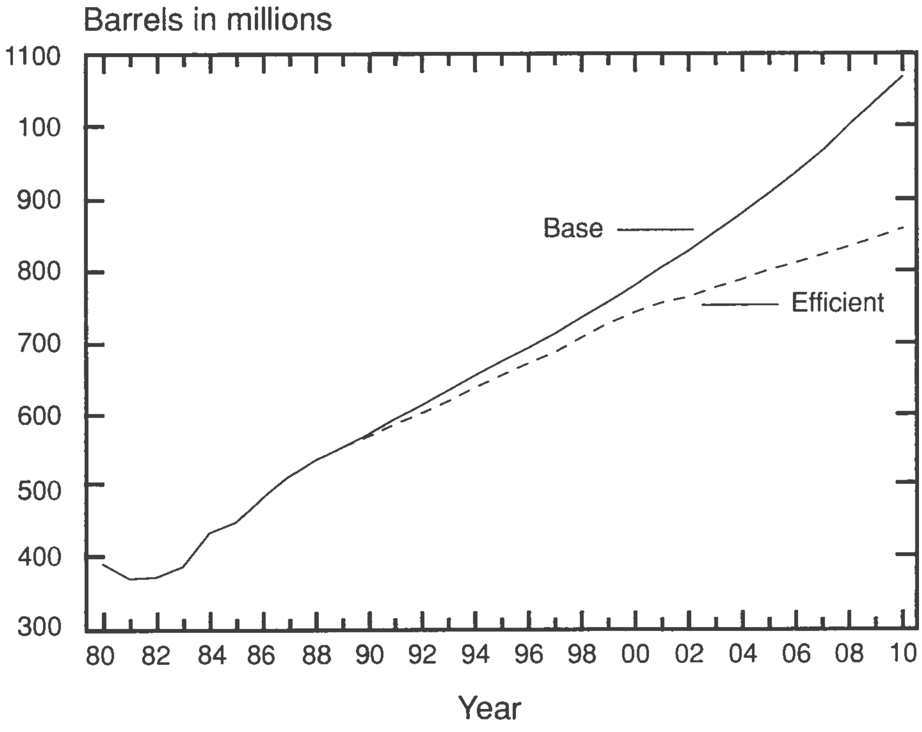

FIGURE 7 U.S. Annual Jet Fuel Consumption Forecast.

Conclusions

California jet fuel consumption will rise by approximately 25% during the 1989–2000 period, followed by a slower increase in 2001–2010. Key factors affecting jet fuel consumption are U.S. GNP, fuel prices, and aircraft fuel efficiency. There are no reasonable policies California can pursue to significantly alter these factors. In the short run, California has limited scope for changing other factors such as airport congestion and aircraft noise limitations because these are largely regulated by the federal government. In the very long run (more than 20 years), policies that shift passengers in the Los Angeles–San Francisco Bay Area corridor to surface modes will reduce California jet fuel consumption, but it is not clear that this will reduce total energy consumption.

DISTILLATE FUEL

Introduction

Distillate fuel for transportation use is primarily diesel fuel used for trucks, railroads, and ships. Distillate fuel accounts for 13% of the transportation Btus in California for 1988 and 20% in the U.S. In 1981, the last year for which data for California are available, 14% of distillate fuel was used by the military, 18% by railroads, 5% by ships, and 63% for on-highway use. There are no statistics for the breakdown of on-highway use for California, but for the U.S. in 1981, trucks consumed 90% of on-highway distillate fuel, cars 5% and buses the remaining 5%. By 1988 these U.S. breakdowns remained the same, except that rail's share declined to 10% and on-highway share increased to 67%.

Given the disparate transportation uses for distillate fuels and the lack of detailed California data on the separate uses, we will use a simple time series model to generate our forecasts. Note that the large majority (97%) of distillate (diesel) fuel is used to haul freight, with trucks, rail, and ships all competing for business. While trucks and rail are almost totally fueled by diesel, all but the smallest ships are fueled by residual fuel oil, which is discussed in the next section of this report. Diesel fuel has also been a competitor with gasoline as a fuel for cars and light trucks. This tradeoff will be discussed further in the policy discussion below, but it appears that emission limits on cars and light trucks will limit diesel use for these vehicles.

Since our forecasts are based on the assumption that California distillate fuel consumption will continue to follow the same historical trends as in the 1964–1988 period, the next subsection will concentrate on evaluating policies that might invalidate this key assumption. The last subsection will present the forecasting model and its results.

Policy Issues

Although there have not been any suggestions that a new generation of fuel-efficient diesel engines is emerging, there has been considerable policy interest in reducing emissions from diesel trucks and buses. The recent federal clean air act mandates reductions in particulate and other diesel emissions beginning in 1994. One of the more popular technologies for reducing diesel emissions, especially for urban transit buses, is to convert the engines to run on methanol. Of course, if there are many such conversions then our projections for future diesel fuel consumption will be too high. Although there does appear to be some evidence that either pure or 85% methanol mixtures will yield substantial ozone reductions for gasoline engines (Walls and Krupnik, 1990), the evidence on methanol's ability to reduce diesel emissions is mixed.

There have been a number of trials with standard transit buses converted to run on methanol, and the Southern California Rapid Transit District (SCRTD) in Los Angeles has just begun testing of transit buses with diesel engines specially designed to run on methanol. The results of the earlier tests are summarized in

Santini and Rajan (1990). Small (1988) and Small and Frederick (1989) perform cost-effectiveness and cost-benefit studies for methanol buses and particulate traps. Although constant-speed dynamometer tests show substantial emission reductions, later tests under more realistic stop-and-go conditions show no decrease in emissions. Methanol with a platinum catalyst can reduce particulate and hydrocarbon emissions, but it does not significantly decrease nitrogen oxides (NO_x). Worse yet, methanol buses emit much higher levels of formaldehyde. Even if emissions are reduced, there are still unknown additional costs associated with increased maintenance and reliability problems relative to standard diesel engines.

Given the reality of the 1994 emission controls, diesel manufacturers are actively pursuing other technologies for meeting the standards. According to *Metro Magazine*, July/August 1989, Volvo and Iveco have both produced prototype combination particulate traps and catalytic converters, which allow current diesel engines to meet the 1994 standards. Detroit Diesel, a major American manufacturer, is also developing particulate traps to be tested on New York City buses. Although the reliability of these systems is unknown, the fact that they can be added to existing engines suggests that the overall vehicle will be more reliable than new methanol diesels. Manufacturers claim that these particulate traps do not affect engine performance or fuel efficiency. If this is true, then adoption of these particulate traps will also not affect our forecasts. The main effect of these traps will be to raise the capital costs of buses and trucks, which in turn will tend to make their operators less sensitive to fuel price changes.

Another possibility, currently being tested in Sweden, is to add steps to the refinery process to clean up diesel fuel. Preliminary results suggest that this clean, low-sulfur fuel combined with standard catalytic converters can also meet emission standards. This technology will, of course, increase the price of diesel fuel, which would tend to make our figures too high. Cleaning up fuel, which is mandated for gasoline by 1995 in the new clean air act, is an appealing policy because it reduces emissions from all vehicles, not just new ones. Small and Frederick (1989) find that although adoption of methanol buses can lead to higher emission reductions, the per unit costs of these reductions are much higher than with cleaner fuel or particulate traps. Their analysis ignores the potentially high maintenance and reliability costs associated with new methanol diesel engines.

Economic efficiency strongly suggests that it is better to set standards and let the marketplace choose the best technology rather than dictate which technology to use. California's policies have promoted methanol as a partial solution to air quality problems. Our review of the current technologies suggest that methanol may be a costly choice for cleaning up diesel engines.

Another policy issue that has received less recent attention is the competition between surface freight modes. For the U.S. in 1988, average truck fleet efficiency was 3460 Btu per ton-mile while water used only 361 Btu per ton-mile and rail 434 Btu per ton-mile. Therefore, if one is interested only in reducing transportation energy use, it is best to shift freight from trucks to either rail or water. Unfortunately, the deregulation of the trucking industry in the late 1970s lowered the relative price of truck transport and therefore increased diesel fuel consumption (Winston, Corsi, Grimm, and Evans, 1990). If the only objective is to reduce fuel consumption, then the efficient solution to this problem is to deregulate rail and charge truckers the full costs of providing the interstate highway system services. This solution is clearly infeasible with current fuel prices, but if it occurred, diesel consumption would be reduced relative to our forecasts. Another option is to subsidize rail service, but Winston shows that the required subsidy levels are politically unrealistic. If domestic water shippers were forced to compete on the same "level playing field" basis (paying full costs for channel dredging and port facilities), then they would probably lose business to rail.

There was a large increase in diesel car and light truck sales in the years immediately following the 1979 oil price shock. The reason for the popularity of diesel in this period can be seen in Figure 8, which shows

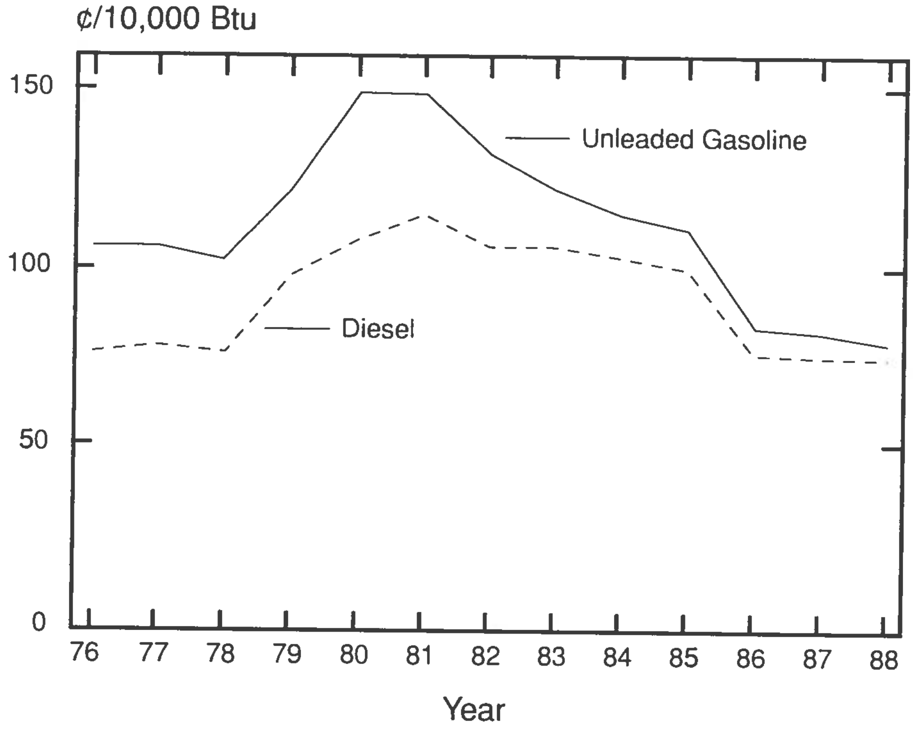

FIGURE 8 U.S. Retail Prices for Motor Fuels.

the price of diesel fuel and unleaded regular gasoline. When the price of unleaded gas dropped in 1984, sales of diesel cars rapidly dropped to almost zero. Even if equivalently large price differences develop in the future, it is unlikely that there will be a resurgence of diesel vehicle purchases because of their difficulty in meeting emission standards.

Air quality concerns have led to the consideration of compressed natural gas (CNG) as a fuel for cars and light trucks. Although CNG definitely reduces emissions, high distribution costs make it unlikely to be used for anything other than centrally fueled fleets in the near future.

Forecasting Model

Since most diesel fuel is used for hauling freight, and since freight movement should be closely related to economic activity, we begin with a simple model relating the log of annual California distillate fuel consumption in millions of barrels (LCADIF) to a 1 year lag in LCADIF and the log of California Gross State Product (GSP) in 1982 dollars (LCGASP82). The estimated model using observations from 1964 to 1986 is given by:

$$\begin{aligned}&\text{LCADIF} =\\&\quad .6 \times \text{LCADIF(1 year earlier)} + 1.18 \times \text{LCGASP82} - 4.54\\&\quad (R^2 = .94)\end{aligned}$$

Figure 9 shows the time series plots of the raw series, and Figure 10 shows that a similar relationship holds for the entire U.S. as well. These results confirm the strong positive correlation between distillate fuel consumption and economic activity.

One difficulty with using the above model is that it requires good predictions for California GSP. We were unable to find a long enough consistent series to generate such a forecast, so we then tried replacing California GSP with U.S. GNP. This model did not fit as well as an even simpler time series model relating LCADIF to a 1-year lagged value. Our actual forecasts are gen-erated from this model fit over the period 1960-1988, and they are shown in Figure 11 along with similar forecasts for the entire U.S. These figures show a 13% growth in California over the 1990-2000 period, followed by 8% growth over the 2000-2010 decade. Because the last year of data, 1988, corresponded to unusually high distillate fuel consumption, the level of our forecasts is probably high. U.S. distillate fuel use has been more stable, and our projections show slightly higher growth than in California.

Conclusions

We predict continued moderate growth in California distillate fuel consumption during the next 20 years. Most of the foreseeable reasons why our forecasts could be wrong suggest that they will be too high. Nevertheless, the scenarios leading to significant reduction in diesel fuel consumption are not likely to occur, especially during the 1990-2000 period. The largest unknown factors are future fuel prices and future technology for reducing diesel emissions.

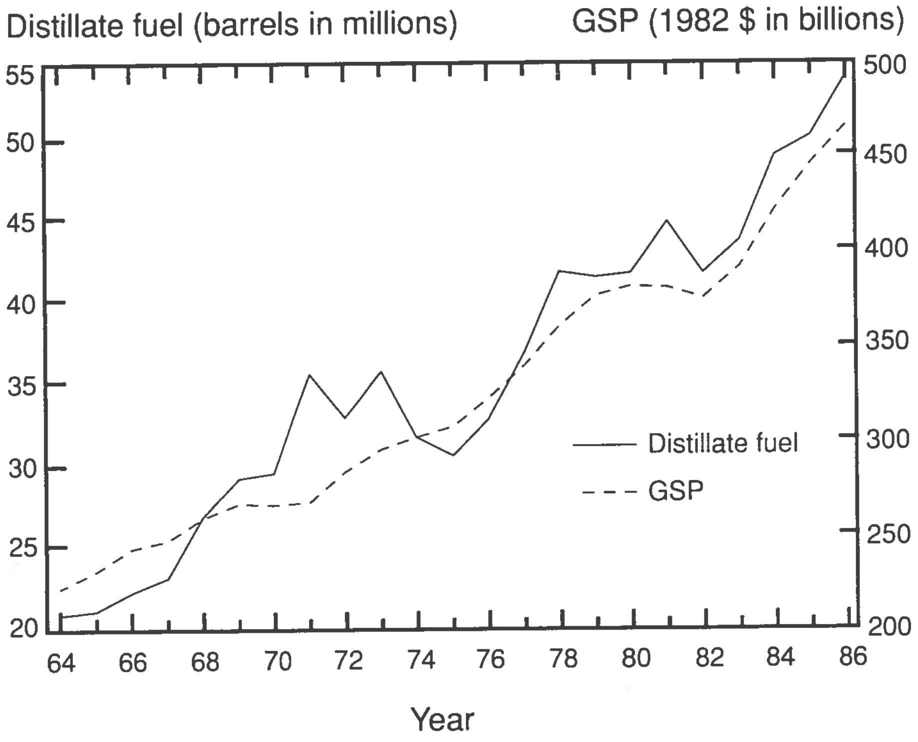

FIGURE 9 California Annual Distillate Fuel Consumption and Gross National Product.

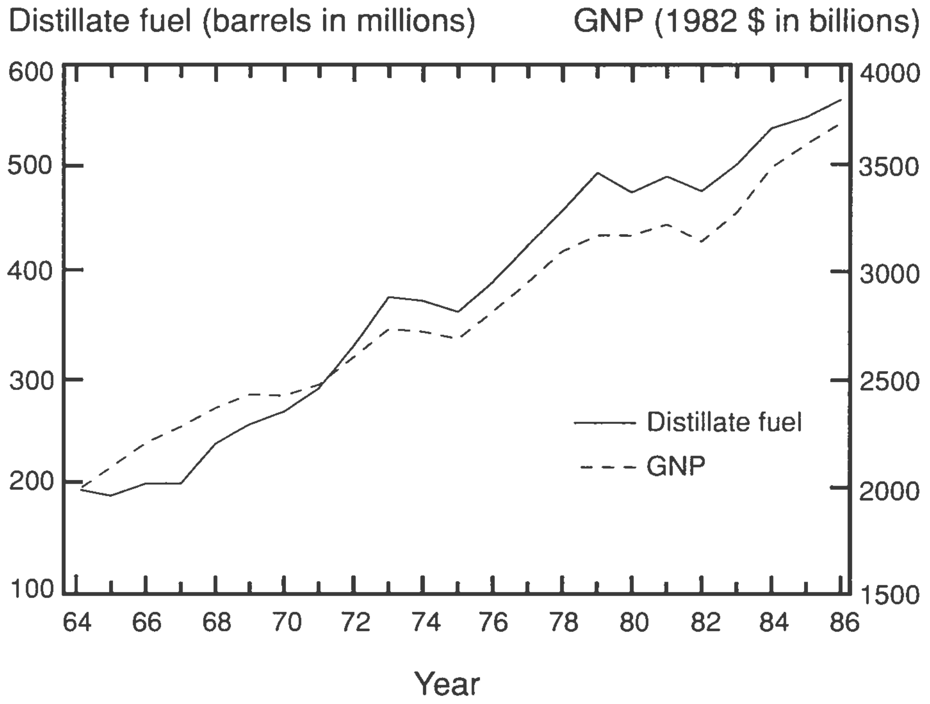

FIGURE 10 U.S. Annual Distillate Fuel Consumption and Gross National Product.

RESIDUAL FUEL

Residual fuel, or bunker fuel, is the very heavy oil left over after the refining process. It is used only in ships and power plants, but emission control regulations prohibit its use in California power plants. Figure 12 shows that residual fuel consumption fluctuates widely and follows no discernible pattern for either California or the U.S. California accounts for approximately 30% of U.S. residual fuel consumption. Although this makes forecasting difficult, from an energy policy perspective we need not worry about residual fuel. Most of the information for this section came from personal communications with Tom Burns, head of the Economics Department, and Dick Parmalee, head of Marine Fuel Marketing at Chevron, a major player in the market.

The total world demand for bunker fuel is stable, smooth, and predictable. A typical large ship can hold enormous amounts of fuel (displacing ballast, if necessary), which allows operators great freedom in choosing fueling locations. Since fuel costs are a large fraction of ship operating costs, ship operators have a strong incentive to look hard for the lowest fuel price. The amount of bunker fuel sold out of California will therefore be extremely sensitive to relative prices between California and alternative ports, which accounts for the large swings in Figure 12. Note that since a large fraction of California shipping is from Asia or through the Panama Canal, the set of alternative ports includes almost the entire world. It is also possible for a ship to take on enough fuel in Indonesia (or California, if cheaper) for a round-trip journey across the Pacific.

From an energy policy perspective, none of this matters very much because California has a large surplus of bunker fuel, which will last for many years. California crude oil is very heavy, while California

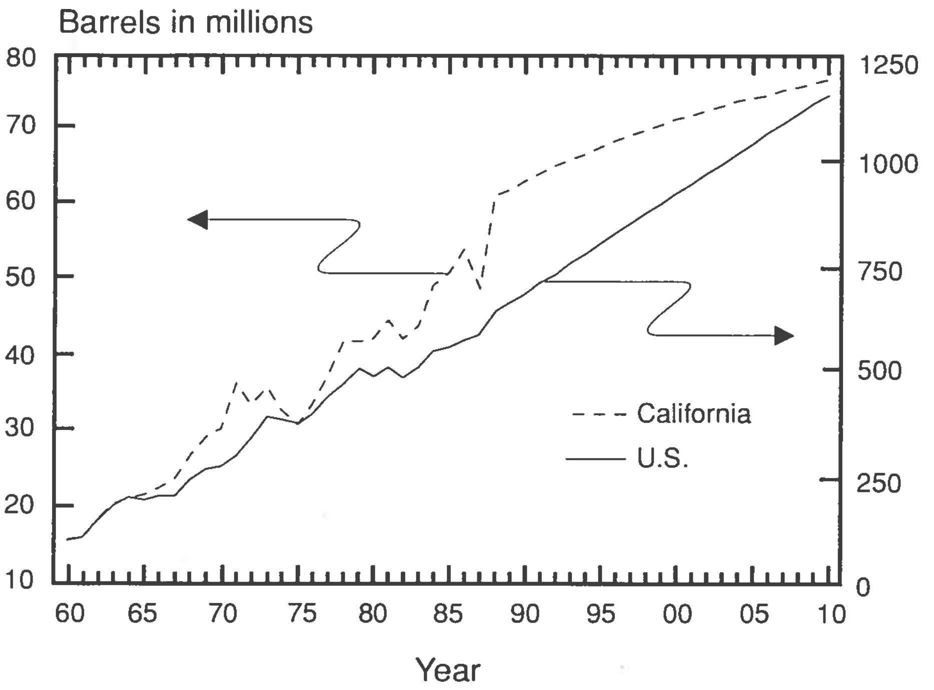

FIGURE 11 California and U.S. Annual Distillate Fuel Consumption Forecasts.

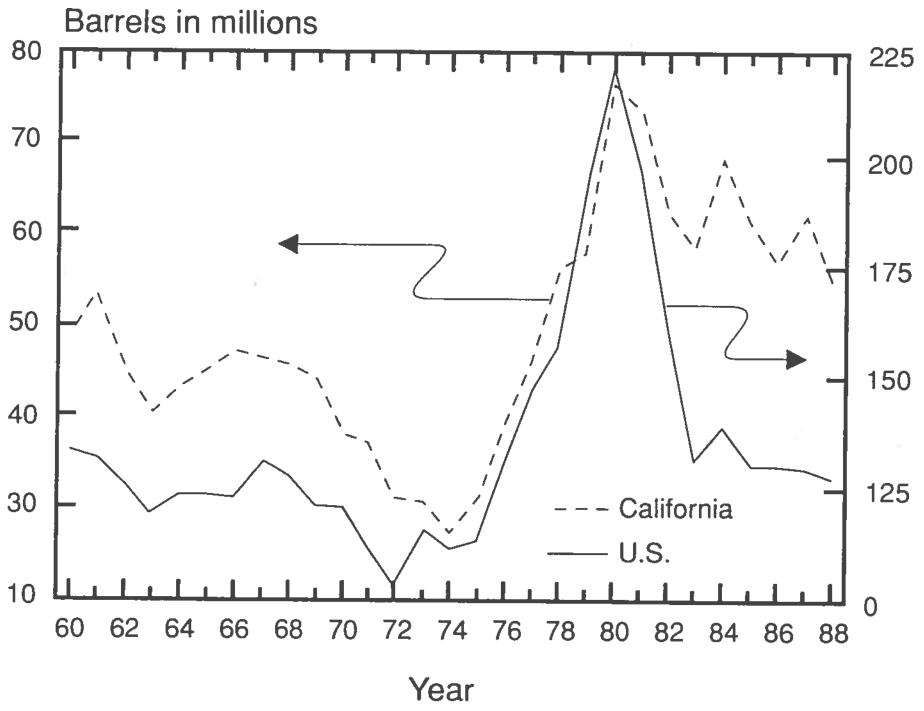

FIGURE 12 California and U.S. Annual Residual Fuel Consumption.

demand is for products, such as gasoline, more easily refined from light crude. With current refining technology, much of a typical barrel of California crude cannot be used in California. Depending on relative prices, this surplus is either shipped east or sold as bunker fuel at California ports. Therefore California will have more than enough bunker fuel available at world prices to service the West Coast shipping trade, which is a small fraction of shipping through our ports.

California refiners would like to reduce this surplus by modifying their refineries to get more profitable gasoline out of a barrel of California crude oil. The current technology for doing this, called "cokers," also increases air pollutant emissions from these refineries. Therefore, unless some new technology emerges soon, it is unlikely that air quality standards will allow much reduction in California's residual fuel surplus.

Since there is no energy policy reason to care about California residual fuel demand, we have not produced any numerical forecasts.

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