Model Developer's Report

for the

Transportation Module

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Appendix F: Model Sensitivities

Solution Methodology

As the description in Section 4 and Appendix B shows, the NEMS Transportation Model is made up of seven semi-independent submodules which address different vehicular modes of the transportation sector. Each submodule also contains methods to deal with the impacts of policy initiatives and legislative mandates which affect individual modes of travel. The transportation sector energy consumption is the sum of the energy consumption forecasts generated through the separate submodules.

The model requires no estimate of the current-year solution to compute the solution to the NEMS Transportation Model. The current year solution depends on only the solution in the previous year, the current economic conditions, and other inputs from the rest of NEMS. However, as shown below, estimates of the current-year fuel prices and economic conditions do influence the forecasts of passenger travel demand, efficiency with which that demand is met, demand for freight transport, and penetration of new technologies. This appendix contains a series of sensitivity analyses to illustrate the behavior of the transportation model in a stand-alone mode. These sensitivities demonstrate how the model responds to changes in key model inputs.

Finally, consumption patterns and model outputs from the NEMS Transportation Model respond reasonably with respect to small model input changes to the most important inputs.

Although rigorous tests have not been performed to determine the maximal ranges and input interdependencies over which the model remains valid, the ranges used for the sensitivity analysis on the important inputs provide an indication of ranges for which the model has proven to be valid. It must be stressed that care be exercised in selecting the proper range, especially with inputs which are correlated so that the model produces interpretable results.

Theoretical Considerations

Because of the direct (rather than iterative) solution algorithm and because all of the functions in the NEMS Transportation Model are continuous and differentiable in the domain of applicability of the model (that is, when "reasonable and consistent inputs" are provided into the model) the model always produces a unique solution. Existence and convergence are not an issue. As previously mentioned, some of the inputs to the model may be correlated (as in certain demographic and macro-economic inputs) and if inconsistent pairs of such inputs or negative prices are chosen, then the model will produce uninterpretable results. When the model is run in a stand-alone fashion, the user must be even more careful, in comparison to use of the full NEMS, in choosing inputs that are individually and jointly sensible.

Examples of assumptions that will cause the model to produce meaningless or infeasible results include:

- characterizing unrealistically "super-efficient" technologies with low acquisition costs,
- modifying prices considerably in excess of variations historically experienced, such as quadrupling prices in one year,
- raising the disposable income to an unrealistic level, and
- exaggerating vehicle survival rates.

Sensitivity Analyses

To show the NEMS Transportation Model's behavior under a variety of situations, several model runs were made to test its sensitivity to altered values for key input variables. These runs are then compared with the Reference Case forecast used for the AEO 94. The sections below describe the six major inputs and outputs chosen for this exercise, as well as the results of the analysis in tabular and graphical form.

Input Variables

The six input variables chosen for the sensitivity analyses were selected based upon their perceived importance in producing the AEO 94 forecast. The six variables and the magnitude of variation from the value used in the AEO forecast are given below.

Motor gasoline and distillate prices. Prices of the two major transportation fuels were each increased by 30 percent every year beginning in 1993, over their values in the AEO 94 Reference Case. Fuel prices affect the projected consumption levels through own and cross price elasticities. Therefore, it is expected that higher fuel prices would result in changes in fuel efficiencies of new vehicles and freight trucks, and sales of alternative-fueled vehicles.

Total Industrial Outputs. Total industrial production by specific industries, which are the macro variables, were increased by 30 percent every year beginning in 1993, over their values in the AEO 94 Reference Case. These variables affect the freight component of the NEMS Transportation Model, which estimates the travel demand for each of the three freight modes: truck, rail, and marine; and the fuel required to meet that demand.

Personal Disposable Income. Personal disposable income, which is a macro variable, was increased by 30 percent every year beginning in 1993, over the value in the AEO 94 Reference Case. The variable primarily affects the regional sales component of the Light Duty Vehicle (LDV) Submodule, the vehicle-miles traveled component of the LDV Stock Submodule, the Air Travel

Demand Submodule, and the Freight Transport Submodule. It is expected that rising income would contribute to the higher miles traveled, fuel consumption, and higher sales of large and high performance vehicles, which consequently would reduce fuel efficiency improvements.

New Car and Light Truck Sales. The total sales of new cars and new light trucks, which are macro variables, were increased by 20 percent every year beginning in 1993, over their values in the AEO 94 Reference Case. The variable affects the regional sales component of the LDV submodule and would contribute to increasing sales of conventional and alternative-fueled vehicles.

Corporate Average Fuel Economy (CAFE) Standards. The assumptions for the CAFE standards used in the AEO 94 Reference Case, which are 27.5 mpg for cars and 20.2 mpg for light trucks, are that they remain constant at 1993 levels. Thus for the sensitivity analysis, the CAFE standards were increased by .5 mile per gallon every year beginning in 1994 for both cars and light trucks. It is expected that fuel efficiency improvements would increase as manufacturers try to meet the standards.

Output Variables

For each input selected, six outputs were chosen to test their sensitivities to these inputs. The six outputs chosen were:

- the fuel efficiencies of the new vehicles and freight trucks,
- the shares of alternative-fueled vehicles,
- the demand for motor gasoline and distillate fuels,
- the demand by light duty vehicles and freight trucks,
- the vehicle miles traveled, and
- the miles traveled by trucks, rail, and ships, and revenue passenger miles (domestic and international).

Tables F-1A through F-3B show the relationship between the inputs and outputs for the years 2000 and 2010. Tables F-1A and F-1B summarize the absolute change of each output relative to the AEO

94 Reference Case for years 2000 and 2010. Similarly, Tables F-2A and F-2B show the percentage change of each output relative to the AEO 94 Reference Case. Tables F-3A and F-3B provide the elasticities (the percentage change of the output divided by the percentage change of the input) of the selected output variables with respect to the selected input variables. Following the tables, a series of six figures displays the long-run elasticities of selected output variables as a time series for each of the six input variable scenarios, respectively. Finally, the summary and conclusions discuss the results presented in the tables and figures.

Figure F-1. Increase Motor Gasoline Price by 30 Percent

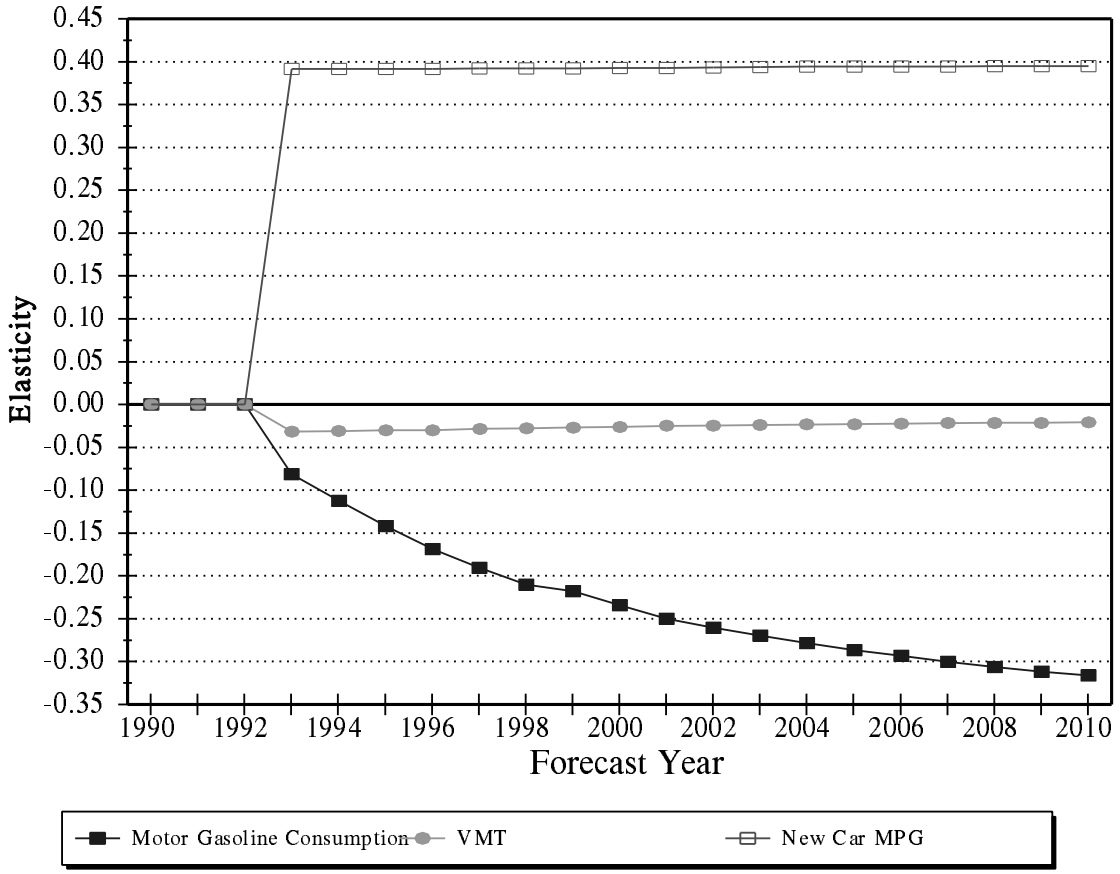


Figure F-2. Increase Distillate Price by 30 Percent

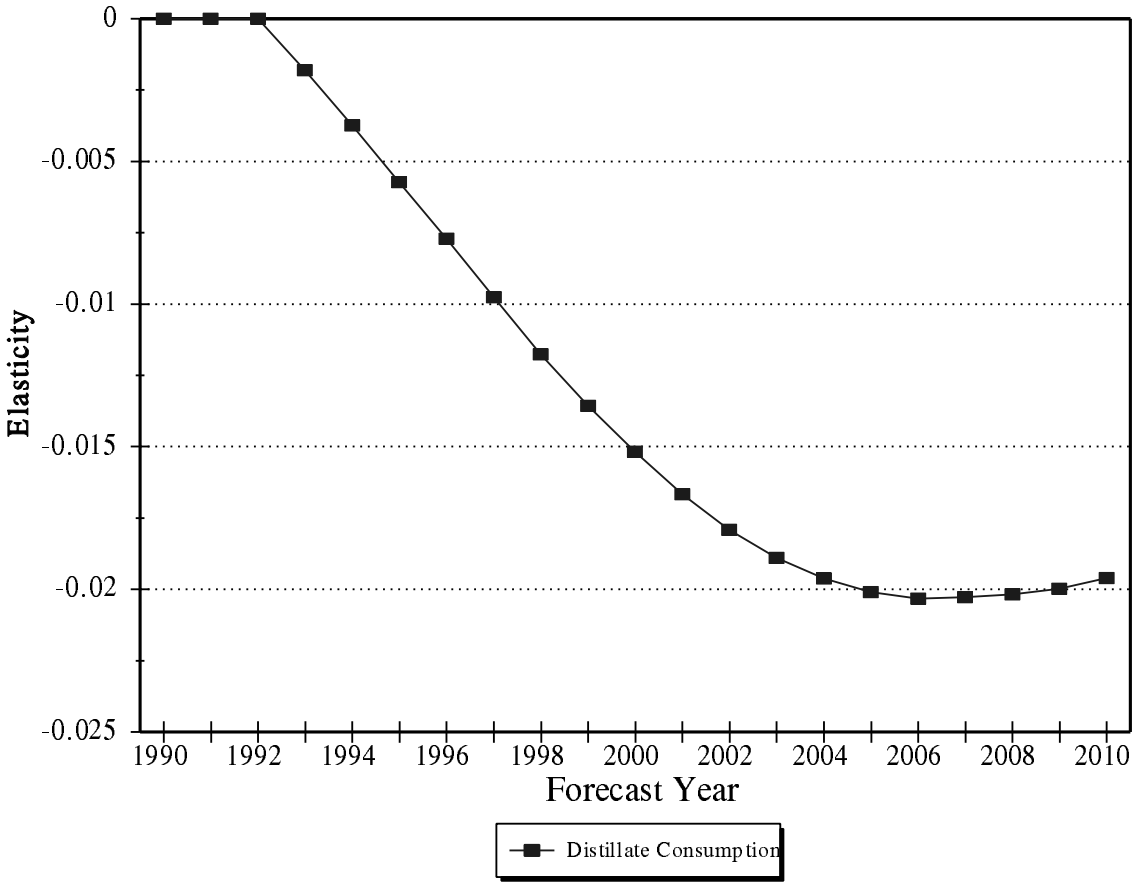


Figure F-3. Increase Total Industrial Outputs by 30 Percent

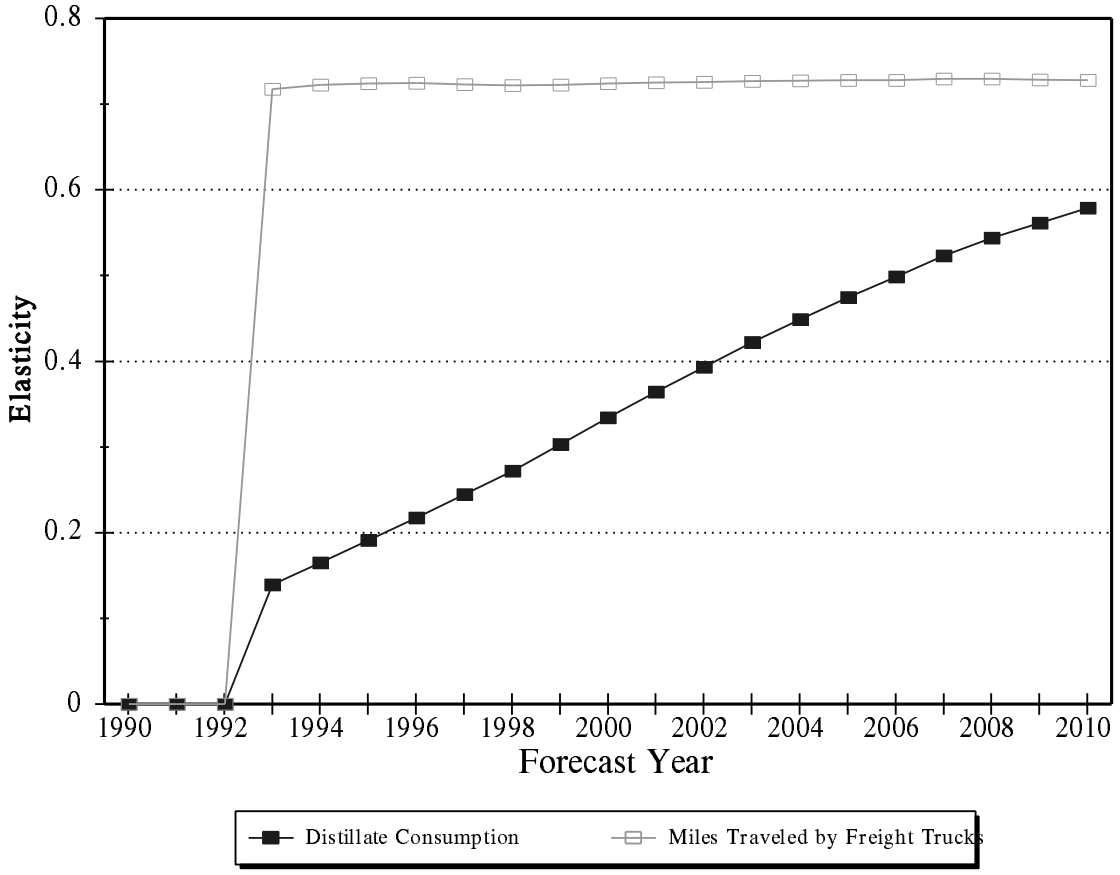


Figure F-4. Increase Disposable Income by 30 Percent

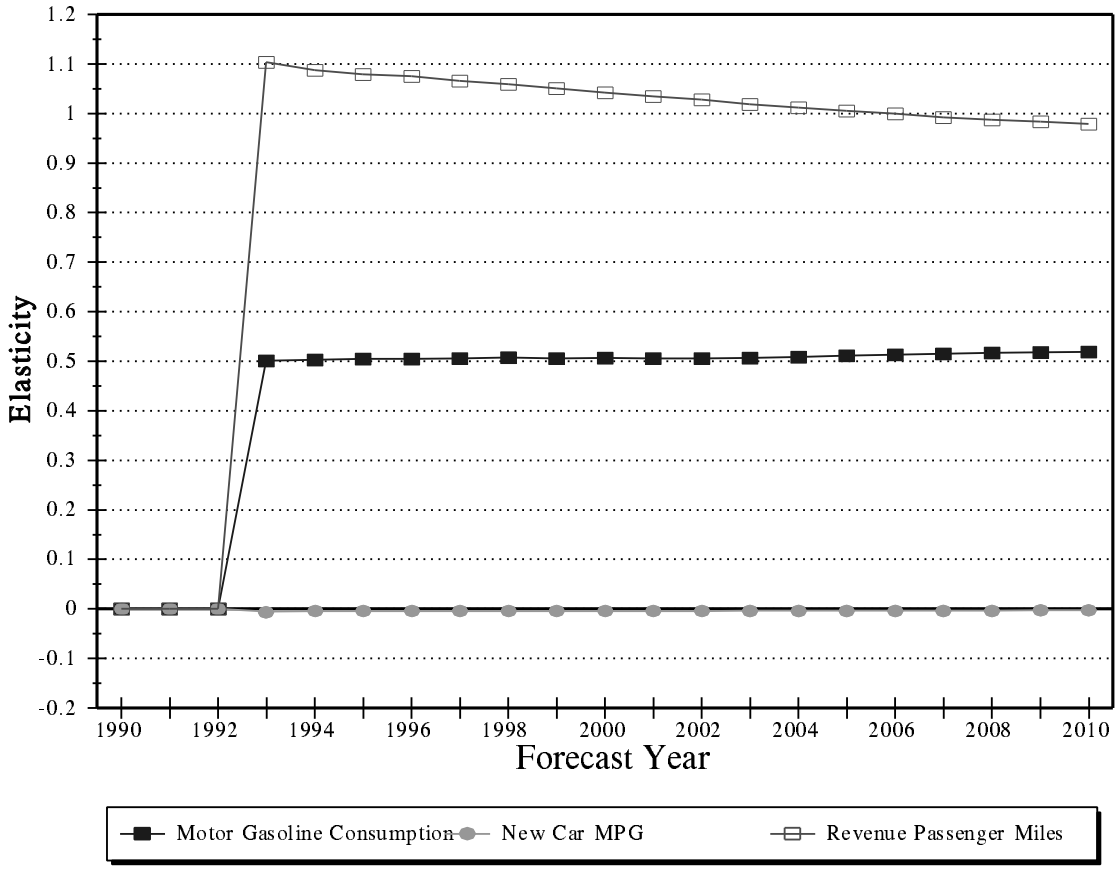


Figure F-5. Increase Total of New Car and Light Truck Sales by 20 Percent

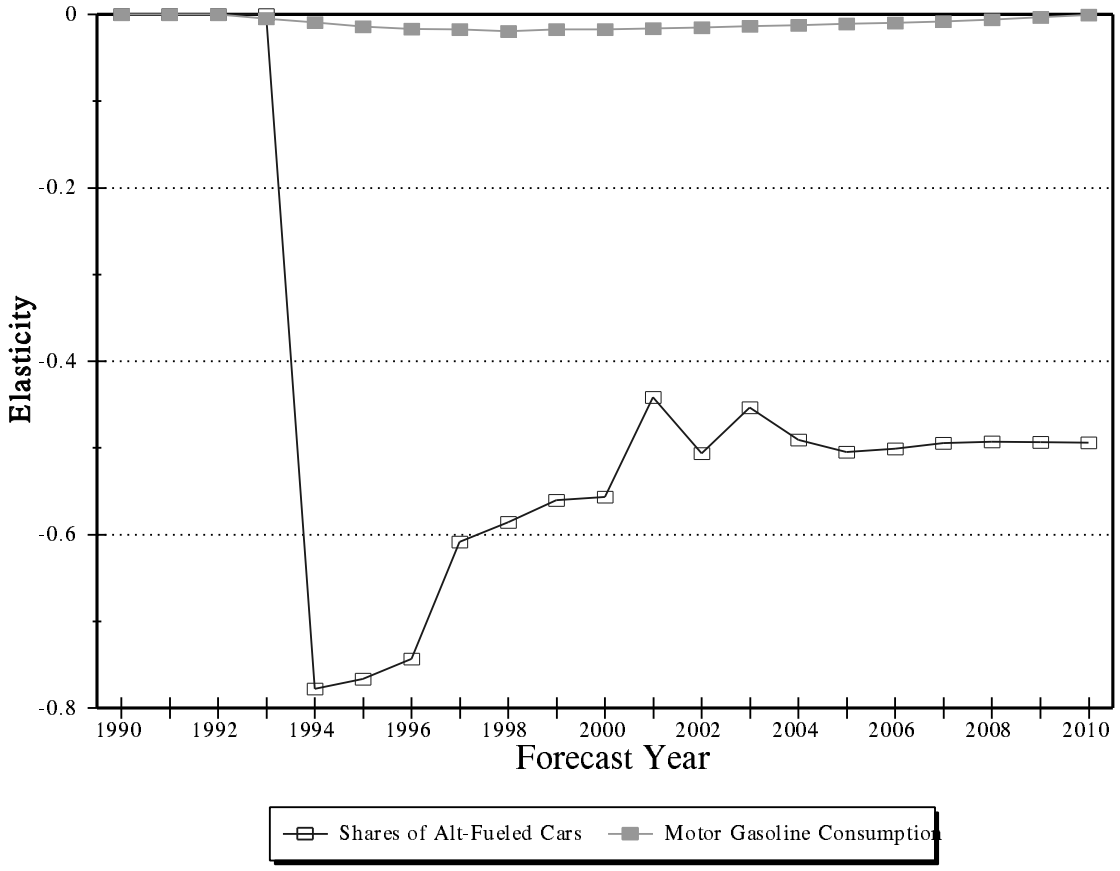
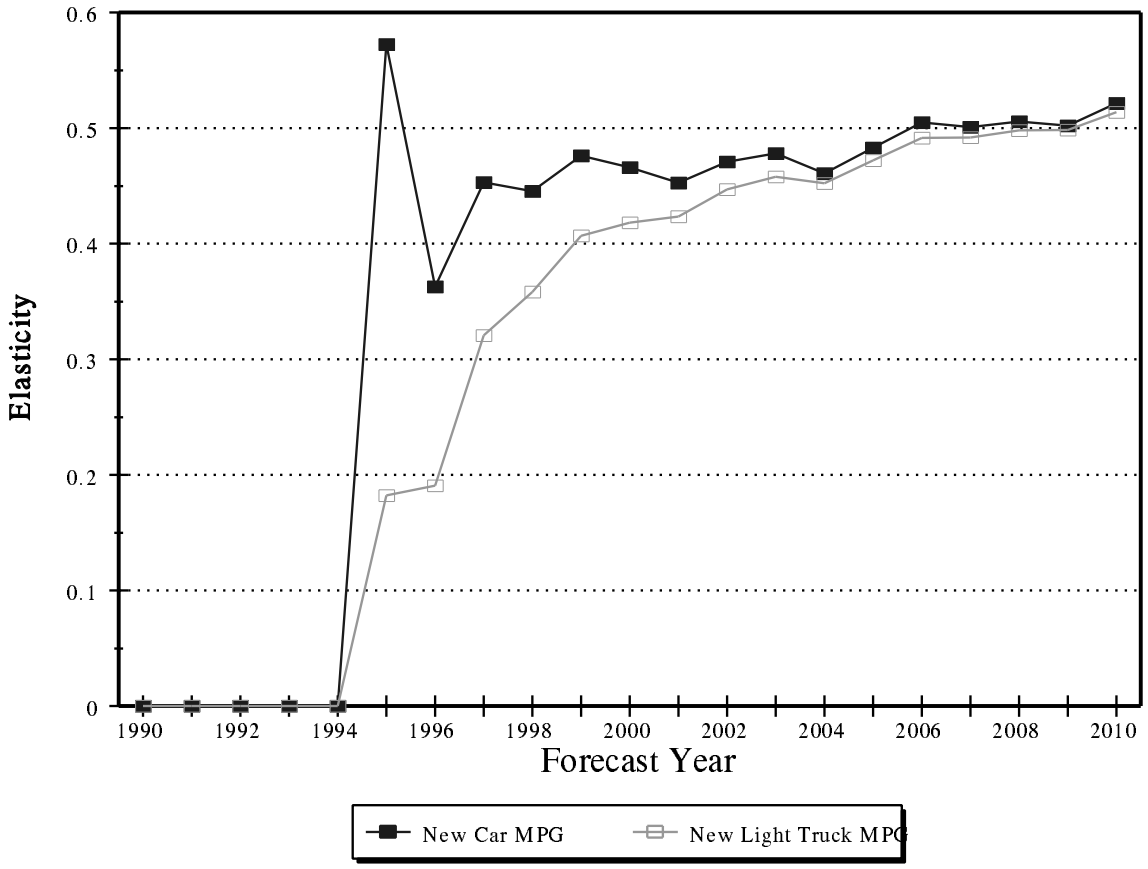


Figure F-6. Increase CAFE Standards by .5 MPG/Year



Summary and Conclusions

Price Responsiveness

As shown on Table F-3B, the NEMS Transportation Model exhibits major fuel own-price elasticities for 2010 in the range of -0.32 (motor gasoline) to -0.02 (distillate). Figures F-1 and F-2 further demonstrate that major fuel price elasticities generally increase over time, reflecting fuel-efficiency improvements as new fuel-saving technologies replace less fuel-efficient equipment. Because the macro feedback is not turned on in these stand-alone runs, there is no macroeconomic activity resulting in no changes in passenger and freight travel demand.

Responsiveness to Total Industrial Outputs

As shown in Table F-1B and Figure F-3, increasing industrial output results in the expected increase in the freight transportation activity among all three modes of truck, rail, and ship. The increase in distillate fuel consumption can be attributed to growth in vehicle-miles traveled by freight trucks, which consume mainly diesel fuel.

Responsiveness to Personal Disposable Income

Table F-2B and Figure 4 show increases in vehicle-miles traveled and revenue passenger miles due to travel demand motivated by rising personal disposable income. Motor gasoline, which is the dominant transportation fuel, experiences a 15.7 percent increase in consumption because personal automobile travel accounts for a significant portion of total energy consumption. Figure F-4 also shows a small decrease in new car mpg due to the inclination toward the purchase of larger and higher performance cars.

Responsiveness to Total Sales of New Cars and Light Trucks

As the total sales of new cars increase by 20 percent, the estimated sales of conventional cars increase from 9.19 million to 11.17 million in year 2010. The estimated sales of alternative-fueled cars also increase from 1.18 million to 1.28 million in year 2010. However, the increase for alternative-fueled cars is nonlinear, which is due to upper limit constraints included in the market

share calculation such as consumer demand and commercial availability of the alternative-fueled technology. The elasticities for market shares of alternative-fueled cars decrease as shown in Figure 5. Fuel consumption is also expected to increase, but the graph shows a slight decrease in motor gasoline consumption. Because the total demand for personal travel depends on the miles traveled per licensed driver and the driving population, which remain constant in this scenario, the total vehicle miles traveled will not change. Thus, no change in vehicle miles traveled, and a small increase in the sale of more fuel-efficient cars result in a small decrease in fuel consumption.

Responsiveness to CAFE Standards

As shown in Figure F-6, manufacturers improve fuel efficiencies for new cars and light trucks as CAFE standards for new cars and light trucks rise.

Table F-1A. Input/Output Matrix - Absolute Change for Year 2000

INPUTS	OUTPUTS											
	Fuel Efficiencies (mpg)					Shares of Alt-Fueled Vehicle (Percent)		Fuel Consumption (Tril. Btu)		Mode Consumption (quad Btu / yr)		VM (billi
	New Vehicles		Freight Trucks			Car	L.Truck	Motor Gas	Dist.	LDV	Frei. Truck	
	Car	L.Truck	Sm.	Med.	Hvy.							
Motor Gasoline Price (30% Increase)	3.49	2.74	.66	.31	.24	.07	.04	-1072	-3.60	-1.10	-.27	-18
Distillate Price (30% Increase)	-.01	0	0	0	0	0	0	0	-.60	0	0	0
Total Industrial Outputs (30% Increase)	0	0	0	0	0	0	0	116	14.3	.13	1.46	0
Disposable Income (30% Increase)	-.04	.09	0	0	0	-.01	.01	2316	19.0	2.34	.56	35
Total cars and light trucks sales (20% Increase)	0	0	0	0	0	-.38	-0.35	-53.0	-7.50	-.07	0	.3
CAFE Standards (.5 mpg / year)	1.75	1.68	0	0	0	.01	0	-252	-.10	-.26	0	2

Table F-1B. Input/Output Matrix - Absolute Change for Year 2010

INPUTS	OUTPUTS											
	Fuel Efficiencies (mpg)					Shares of Alt-Fueled Vehicle (Percent)		Fuel Consumption (Tril. Btu)		Mode Consumption (quad Btu / yr)		VM (billi
	New Vehicles		Freight Trucks			Car	L.Truck	Motor Gas	Dist.	LDV	Frei. Truck	
	Car	L.Truck	Sm.	Med.	Hvy.							
Motor Gasoline Price (30% Increase)	3.75	3.02	.73	.33	.24	.33	.24	-1522	-5.8	-1.61	-.32	-17
Distillate Price (30% Increase)	0	0	0	0	0	0	0	1.00	-1.10	0	0	0
Total Industrial Outputs (30% Increase)	0	0	0	0	0	0	0	119	30.1	.14	1.67	0
Disposable Income (30% Increase)	-.02	.08	0	0	0	-.03	.06	2498	17.5	2.58	.63	41
Total cars and light trucks sales (20% Increase)	.01	-.01	0	0	0	-1.12	-.56	-2.00	-4.40	-.03	0	.3
CAFE Standards (.5 mpg / year)	5.10	5.45	0	0	0	.04	.02	-1156	-.50	-1.24	0	7.0

Table F-2A. Input/Output Matrix - Percentage Change for Year 2000

INPUTS	OUTPUTS											
	Fuel Efficiencies (mpg)					Shares of Alt-Fueled Vehicle (Percent)		Fuel Consumption (Tril. Btu)		Mode Consumption (quad Btu / yr)		VM (billi
	New Vehicles		Freight Trucks			Car	L.Truck	Motor Gas	Dist.	LDV	Frei. Truck	
	Car	L.Truck	Sm.	Med.	Hvy.							
Motor Gasoline Price (30% Increase)	11.77	11.81	4.31	4.38	4.35	1.88	1.27	-7.02	-2.57	-7.03	-3.97	-.7
Distillate Price (30% Increase)	0	0	0	0	0	0	0	.01	-.46	0	0	0
Total Industrial Outputs (30% Increase)	0	0	0	0	0	0	0	.76	10.03	.83	21.16	0
Disposable Income (30% Increase)	-.12	.40	0	0	0	-.25	.40	15.18	13.28	14.99	8.15	15.2
Total cars and light trucks sales (20% Increase)	.02	-.03	0	0	0	-11.13	-12.18	-.34	-5.26	-.40	-.02	.01
CAFE Standards (.5 mpg / year)	5.93	7.25	0	0	0	.14	.10	-1.65	-.07	-1.66	0	.06

Table F-2B. Input/Output Matrix - Percentage Change for Year 2010

INPUTS	OUTPUTS											
	Fuel Efficiencies (mpg)					Shares of Alt-Fueled Vehicle (Percent)		Fuel Consumption (Tril. Btu)		Mode Consumption (quad Btu / yr)		VM (billi
	New Vehicles		Freight Trucks			Car	L.Truck	Motor Gas	Dist.	LDV	Frei. Truck	
	Car	L.Truck	Sm.	Med.	Hvy.							
Motor Gasoline Price (30% Increase)	11.85	11.97	4.32	4.36	4.23	2.91	3.66	-9.49	-3.33	-9.42	-3.98	-.6
Distillate Price (30% Increase)	0	0	0	0	0	0	0	.01	-.59	0	0	0
Total Industrial Outputs (30% Increase)	0	0	0	0	0	0	0	.74	17.36	.82	21.32	0
Disposable Income (30% Increase)	-.09	.31	0	0	0	-.27	.90	15.57	10.12	15.20	8.04	15.3
Total cars and light trucks sales (20% Increase)	.03	-.05	0	0	0	-9.87	-8.37	-.01	-2.52	-.18	-.01	.01
CAFE Standards (.5 mpg / year)	16.12	21.61	0	0	0	.34	.33	-7.20	-.27	-7.29	0	.28

Table F-3A. Input/Output Matrix - Elasticities for Year 2000

INPUTS	OUTPUTS											
	Fuel Efficiencies (mpg)					Shares of Alt-Fueled Vehicle (Percent)		Fuel Consumption (Tril. Btu)		Mode Consumption (quad Btu / yr)		VM (billi
	New Vehicles		Freight Trucks			Car	L.Truck	Motor Gas	Dist.	LDV	Frei. Truck	
	Car	L.Truck	Sm.	Med.	Hvy.							
Motor Gasoline Price (30% Increase)	.39	.39	.14	.15	.14	.06	.04	-.23	-.09	-.23	-.13	-.0
Distillate Price (30% Increase)	0	0	0	0	0	0	0	0	-.02	0	0	0
Total Industrial Outputs (30% Increase)	0	0	0	0	0	0	0	.03	.33	.03	.71	0
Disposable Income (30% Increase)	0	.01	0	0	0	-.01	.01	.51	.44	.50	.27	.5
Total cars and light trucks sales (20% Increase)	0	0	0	0	0	-.56	-.61	-.02	-.26	-.02	0	0
CAFE Standards (.5 mpg / year)	.47	.57	0	0	0	.01	.01	-.13	-.01	-.13	0	0

Table F-3B. Input/Output Matrix - Elasticities for Year 2010

INPUTS	OUTPUTS											
	Fuel Efficiencies (mpg)					Shares of Alt-Fueled Vehicle (Percent)		Fuel Consumption (Tril. Btu)		Mode Consumption (quad Btu / yr)		VM (billi
	New Vehicles		Freight Trucks			Car	L.Truck	Motor Gas	Dist.	LDV	Frei. Truck	
	Car	L.Truck	Sm.	Med.	Hvy.							
Motor Gasoline Price (30% Increase)	.39	.40	.14	.15	.14	.10	.12	-.32	-.11	-.31	-.13	-.0
Distillate Price (30% Increase)	0	0	0	0	0	0	0	0	-.02	0	0	0
Total Industrial Outputs (30% Increase)	0	0	0	0	0	0	0	.02	.58	.03	.71	0
Disposable Income (30% Increase)	0	.01	0	0	0	-.01	.03	.52	.34	.51	.27	.5
Total cars and light trucks sales (20% Increase)	0	0	0	0	0	-.49	-.42	0	-.13	-.01	0	0
CAFE Standards (.5 mpg / year)	.52	.70	0	0	0	.01	.01	-.23	-.01	-.24	0	.0