MODEL SENSITIVITY TESTING

A number of tests were performed to evaluate the sensitivity of the household travel models to changes in various inputs. Other modules of the model were not run for these tests. Sensitivity tests from full model runs will be reported on in a later version of the documentation.

Most of the sensitivity tests measure the amount of change in household DVMT that occurs with changes to each of the following factors: household income, fuel price, population density, freeway supply, public transit supply, and fuel economy. A test of sensitivity of fuel consumption to vehicle fuel economy was also run to measure the size of the rebound effect. This is the reduction in the impact of MPG improvements on fuel consumption due to the effect of reduced per mile fuel cost on household DVMT.

The tests were performed using the NHTS household survey dataset used for model estimation. The model sensitivity to each variable is reported as the ratio between the percentage change in model outputs (i.e. DVMT, fuel consumption) to the percentage change in the variable of interest. These ratios are calculated as arc elasticities.

Elasticities were also computed for households grouped by population density, land use form, and household income. How the elasticity measures vary with respect to these groupings can provide useful insight into how the model is working. However, it is important to note that, since these results are simply tabulated from the household survey groupings, they do not necessarily show the joint effect of the two variables. The results are also influenced by correlated attributes.

This section reports these elasticities and compares them to results of several other studies. The purpose of these comparisons is to determine whether the sensitivities of the GreenSTEP models are within a reasonable range of results found by other studies. The purpose is not to achieve any particular elasticity targets because, in reality, there are no established targets. Different studies produce different elasticity estimates because of the way in which a study is done, and the data used will affect the results.

Studies differ from one another in several ways.[39] A basic difference is whether the model that is produced is based on longitudinal (time series) data or cross-sectional (single time) data. Longitudinal models directly estimate elasticity through the comparison of when and by how much the variables change over time. Cross-sectional models do not directly estimate elasticity but can be used to calculate elasticity by comparing how much model results change when an input variable such as fuel price is changed. Both short-term and long-term elasticities can be calculated with longitudinal studies. The results from cross-sectional modeling represent long-term elasticity.

[39] Transportation Research Board, 2009. Add page/section reference

Models also differ in the number of factors considered in the analysis. This is often the result of limitations in the data that are available. Longitudinal modeling studies typically consider many fewer variables than cross-sectional studies because of the lack of availability of time-series data.

Finally, models differ in the level of aggregation of the study units. The GreenSTEP models are very disaggregate because they model the responses of individual households to factors that affect vehicle travel. In contrast, the study units of many longitudinal models are much more aggregate (e.g. statewide VMT) because of data limitations.

Population Density Sensitivity

Table 59 shows elasticity estimates of household DVMT with respect to population density vary from -0.07 to -0.08 for density increases of 10% to 50%. In other words, a 50% increase in density would result in a 4 per cent decrease in average household DVMT. The elasticity is about 4 times higher in urban mixed type areas. These values are comparable to the findings of TRB Special Report 298:

> *Studies aimed at isolating the effect of residential density while controlling for sociodemographic and other land use variables consistently find that doubling density is associated with about 5 percent less VMT on average; one rigorous California study finds that VMT is lower by 12 percent. The same body of literature, mainly U.S.-based studies, reports that VMT is lower by an average of 3 to 20 percent when other land use factors that often accompany density, such as mixed uses, good design, and improved accessibility are accounted for, and suggests further that in some cases these reductions are additive.*[40]

Population density elasticity increases with increasing density and decreases with increasing income.

Table 56. Population Density Elasticity of Household DVMT
10% to 50% Changes in Census Tract Population Density

	10% Density Change	**20% Density Change**	**30% Density Change**	**40% Density Change**	**50% Density Change**	**N**
Overall						
	-0.07	-0.07	-0.07	-0.08	-0.08	9748
Density (Population/ Square Mile)						
< 1,000	-0.01	-0.01	-0.01	-0.01	-0.01	2356
1,000 to 5,000	-0.04	-0.04	-0.04	-0.04	-0.05	3502
5,000 to 10,000	-0.12	-0.12	-0.13	-0.13	-0.14	2935
> 10,000	-0.37	-0.39	-0.41	-0.42	-0.44	955
Urban Form						

[40] Transportation Research Board, 2009. Add page/section reference

Urban Mixed Type	-0.20	-0.20	-0.21	-0.22	-0.23	2726
Other	-0.05	-0.05	-0.05	-0.06	-0.06	7022
Income (Thousand Dollars)						
0 to 40	-0.09	-0.09	-0.09	-0.10	-0.10	3246
40 to 80	-0.07	-0.07	-0.07	-0.07	-0.08	3590
80 Plus	-0.06	-0.07	-0.07	-0.07	-0.07	2912

Freeway Supply Sensitivity

Table 60 shows elasticity estimates of household DVMT with respect to freeway supply to vary from 0.06 to 0.07 for freeway supply increases from 10% to 50%. In other words, a 50% increase in freeway supply would result in a 3.5% increase in average household DVMT. Elasticity increases only slightly as the amount of change in freeway supply increases.

Elasticity decreases in higher density and urban mixed type areas. This seems reasonable because in higher density and urban mixed type areas, activities are located closer together and more modes of transportation are available, so the marginal effect of improvements in freeway travel times on auto mode choice and travel distance will be smaller.

Elasticity decreases slightly as income increases.

A large number of studies have been done to estimate the elasticity of vehicle travel with respect to road supply (lane-miles). There is a substantial amount of variation in the results, with elasticities ranging from 0.1 to 1.0.[41] This variation is a result of differences in the designs, assumptions, data and methodologies used in the studies.

Many of the studies are longitudinal and so evaluate the time relationships between road supply increases and VMT increases. Some of these studies also calculate high elasticity values and assume that, if road expansion occurs prior to VMT increases, then the effect must be causal from road supply to VMT. This assumption is questionable given that many road expansion projects are planned well in advance of construction and are sized to accommodate anticipated or planned development. Cervero[42] used a path analysis approach to capture the interdependencies between road supply, road speeds, travel demand, and development activity in order to better sort out causal effects. Using this approach, he estimated that increases in vehicle travel due to behavioral changes used 31 per cent of added capacity on average, and land use changes caused VMT increases using another 9 per cent. Other external factors, such as growth in population and income, used another 40 per cent, leaving 20 per cent of the capacity remaining.

[41] Strathman et al, 2000, Table 1.
[42] Cervero, July 2001 and Spring 2003.

Table 57. Freeway Supply Elasticity of Household DVMT
10% to 50% Changes in Metropolitan Freeway Lane-Miles Per Capita

	10% Ln-Mi Change	**20% Ln-Mi Change**	**30% Ln-Mi Change**	**40% Ln-Mi Change**	**50% Ln-Mi Change**	**N**
Overall						
	0.06	0.06	0.06	0.06	0.07	9748
Density (Population/ Square Mile)						
< 1,000	0.06	0.06	0.06	0.07	0.07	2356
1,000 to 5,000	0.06	0.06	0.06	0.06	0.07	3502
5,000 to 10,000	0.05	0.06	0.06	0. 06	0.06	2935
> 10,000	0.05	0.05	0.05	0. 06	0.06	955
Urban Form						
Urban Mixed Type	0.05	0.05	0.06	0.06	0.06	2726
Other	0.06	0.06	0.06	0.06	0.07	7022
Income (Thousand Dollars)						
0 to 40	0.06	0.06	0.07	0.07	0.07	3246
40 to 80	0.06	0.06	0.06	0.06	0.07	3590
80 Plus	0.05	0.05	0.06	0.06	0.06	2912

Strathman et al. developed a model from 1995 National Personal Travel Survey (NPTS) data that jointly determined population density, employment density, commute mode choice, and VMT. [43] The road supply elasticity of VMT estimated with their model was 0.29.

Differences in elasticity estimates also result from differences in how VMT is counted. Studies that count VMT on one or more specific roadways or roadway types tend to produce higher elasticity estimates (ceteris paribus) because diverted traffic from uncounted facilities will be attributed to a VMT increase on the counted facilities. Corridor studies that count VMT on all roadways within a corridor help to control for the effect of traffic diversions, but still miss larger scale diversions from other corridors or other destinations. Metropolitan-wide studies that count VMT on all roads produce lower elasticity estimates because traffic shifts among routes and destinations will not bias the results. The GreenSTEP model estimates can be expected to be even lower because these estimates are based on changes in total household VMT, not just household VMT on metropolitan area roadways.

Estimates from studies also differ based on the modeling approach and the variables used in the model. This affects the results of observational studies because there is correlation between variables (although highly correlated variables are avoided) and so the estimated coefficient for any particular variable will depend on what other related variables are

[43] Strathman et al, 2000.

included in the model. For example, urban areas that have a more extensive freeway system also tend to be less dense and have less land use mixing. A model that includes freeway supply but excludes density and mixed use will have a larger coefficient on the freeway term than will a model which includes all three variables.

Finally, it should be noted that long term changes in VMT are due in part to changes in land development that occur in response to changes in the road system. For example, Cervero estimated that land use changes occurring as a result of roadway expansions accounted for the use of 9 per cent of added road capacity. Studies that measure this effect will produce higher elasticity estimates than studies that do not. The sensitivity test results reported here, unlike the Cervero and Strathman studies, do not consider any changes in land use as a result of freeway expansion. The key land use variables in the GreenSTEP models (population density and urban development type) are calculated from inputs to the model and are not determined endogenously.

In conclusion, the elasticity of travel with respect to freeway supply is low compared to numbers reported in the literature. However, since the studies behind the reports vary greatly in their geographic scope, other characteristics considered (economic, land use, demographic), and methodological approach, it hard to say whether the GreenSTEP model is insufficiently sensitive. The large geographic scope of the model, aggregate measurement of freeway supply, and inclusion of many variables, and disaggregate (household level) approach in GreenSTEP could greatly limit model sensitivity. However, even if the GreenSTEP model is not as sensitive as it should be the consequences in model application would be minimal because it is highly unlikely that any of the scenarios to be modeled will propose anything but minimal increases in freeway supply.

Transit Supply Sensitivity

Table 61 shows elasticity estimates of household DVMT with respect to transit supply to vary from -0.04 and -0.05 for transit supply increases from 10% to 50%. In other words, 50% increase in public transit revenue miles would result in a 2.5% decrease in average household DVMT.

Table 58. Transit Supply Elasticity of Household DVMT
10% to 50% Increases in Metropolitan Transit Revenue Miles Per Capita

	10% Rev-Mi Change	**20% Rev-Mi Change**	**30% Rev-Mi Change**	**40% Rev-Mi Change**	**50% Rev-Mi Change**	**N**
Overall						
	-0.04	-0.05	-0.05	-0.05	-0.05	9748
Density (Population/ Square Mile)						
< 1,000	-0.01	-0.01	-0.01	-0.02	-0.02	2356
1,000 to 5,000	-0.03	-0.03	-0.03	-0.03	-0.03	3502
5,000 to 10,000	-0.07	-0.07	-0.07	-0.08	-0.08	2935
> 10,000	-0.21	-0.22	-0.23	-0.23	-0.24	955
Urban Form						
Urban Mixed Type	-0.11	-0.11	-0.12	-0.12	-0.13	2726
Other	-0.03	-0.04	-0.04	-0.04	-0.04	7022
Income (Thousand Dollars)						
0 to 40	-0.05	-0.05	-0.06	-0.06	-0.06	3246
40 to 80	-0.04	-0.04	-0.05	-0.05	-0.05	3590
80 Plus	-0.04	-0.04	-0.05	-0.05	-0.05	2912

- As Table 58 shows, elasticity increases substantially at higher densities and in urban mixed use areas. This is sensible because higher densities and mixed use development make public transit more competitive with automobile travel by shortening travel distances and increasing transit access.

There transit supply elasticity decreases slightly with respect to income. The transit elasticities are consistent with the range of transit elasticities of driving to work estimated by Bento et al: -0.03 (excluding New York) to -0.07.[44]

[44] Bento et al, 2005, in Transportation Research Board 2009. In that study, transit supply is measured by route miles rather than revenue miles.

Household Income Sensitivity

Table 62 shows elasticity estimates of metropolitan household DVMT with respect to household income to be 0.28 for all income changes. In other words, a 50% increase in household income would result in a 14% increase in average household DVMT.

Table 59. Income Elasticity of Metropolitan Household DVMT
10% to 50% Increases in Household Income

	10% Income Change	**20% Income Change**	**30% Income Change**	**40% Income Change**	**50% Income Change**	**N**
Overall						
	0.28	0.28	0.28	0.28	0.28	9748
Density (Population/ Square Mile)						
< 1,000	0.28	0.28	0.28	0.28	0.28	2356
1,000 to 5,000	0.28	0.28	0.28	0.28	0.28	3502
5,000 to 10,000	0.29	0.29	0.29	0.29	0.29	2935
> 10,000	0.31	0.31	0.31	0.31	0.31	955
Urban Form						
Urban Mixed Type	0.30	0.30	0.30	0.30	0.30	2726
Other	0.28	0.28	0.28	0.28	0.28	7022
Income (Thousand Dollars)						
0 to 40	0.33	0.33	0.33	0.32	0.32	3246
40 to 80	0.28	0.28	0.28	0.28	0.28	3590
80 Plus	0.27	0.27	0.27	0.27	0.27	2912

There is a small increase in income elasticity as population density increases.

These income elasticity estimates are lower, but not greatly so, than the range of income elasticities (0.35 – 0.37) computed previously by Pickrell and Schimek from 1995 NPTS data.[45]

Table 63 shows elasticity estimates of non-metropolitan household DVMT with respect to household income to be close to the estimates for metropolitan households. Elasticities are close to the metropolitan household elasticities.

[45] Don Pickrell and Paul Schimek, Trends in Personal Motor Vehicle Ownership and Use: Evidence from the Nationwide Personal Transportation Survey, U.S. DOT Volpe Center, Cambridge, MA, April 23, 1998, http://nhts.ornl.gov/1995/Doc/Envecon.pdf

Table 60. Income Elasticity of Non-metropolitan Household DVMT
10% to 50% Increases in Household Income

	10% Income Change	20% Income Change	30% Income Change	40% Income Change	50% Income Change	N
Overall						
	0.28	0.28	0.28	0.28	0.28	9312
Density (Population/ Square Mile)						
< 1,000	0.28	0.28	0.28	0.28	0.28	6217
1,000 to 5,000	0.27	0.27	0.27	0.27	0.27	2321
5,000 to 10,000	0.29	0.29	0.29	0.29	0.29	733
> 10,000	0.33	0.33	0.33	0.32	0.32	50
Urban Form						
Urban Mixed Type	0.28	0.28	0.28	0.28	0.28	9232
Other	0.28	0.28	0.28	0.28	0.28	89
Income (Thousand Dollars)						
0 to 40	0.32	0.31	0.31	0.31	0.31	4725
40 to 80	0.26	0.26	0.26	0.26	0.26	3303
80 Plus	0.25	0.25	0.25	0.25	0.25	1293

Fuel Price Sensitivity

Table 64 shows fuel price elasticity estimates of metropolitan household DVMT to vary from -0.01 and -0.02 for fuel price changes between 10% and 50%. Table 65 shows elasticity to vary between -0.05 and -0.29 for fuel price changes between 100% and 500%. Tables 26 and 27 showed calculated elasticities over an even wider range of prices.

Elasticities increase as prices increase because as a consequence of the approach taken in GreenSTEP to account for the effects of costs on vehicle travel. This approach replicates recent trends which showed very little change in vehicle travel in response to increases in gas prices, but also is responsive to large increases in gas (or other) prices.

Table 66 and 67 show fuel price elasticity estimates of non-metropolitan household DVMT. The overall elasticity values are higher than for metropolitan households. Moreover, fuel price elasticity for these households varies much more with household income.

Table 61. Fuel Price Elasticity of Metropolitan Household DVMT
Given 20 and 40 Per Cent Changes in Fuel Price

	10% Price Change	**20% Price Change**	**30% Price Change**	**40% Price Change**	**50% Price Change**	**N**
Overall						
	-0.01	-0.01	-0.02	-0.02	-0.02	9748
Density (Population/ Square Mile)						
< 1,000	-0.02	-0.02	-0.02	-0.03	-0.03	2356
1,000 to 5,000	-0.01	-0.01	-0.02	-0.02	-0.02	3502
5,000 to 10,000	-0.01	-0.01	-0.01	-0.02	-0.02	2935
> 10,000	-0.01	-0.01	-0.01	-0.01	-0.01	955
Urban Form						
Urban Mixed Type	-0.01	-0.01	-0.01	-0.01	-0.02	2726
Other	-0.01	-0.02	-0.02	-0.02	-0.03	7022
Income (Thousand Dollars)						
0 to 40	-0.05	-0.06	-0.07	-0.07	-0.08	3246
40 to 80	-0.00	-0.01	-0.01	-0.01	-0.02	3590
80 Plus	-0.00	-0.00	-0.00	-0.00	-0.00	2912

Table 62. Fuel Price Elasticity of Metropolitan Household DVMT
Given 100 to 500 Per Cent Changes in Fuel Price

	100% Price Change	**200% Price Change**	**300% Price Change**	**400% Price Change**	**500% Price Change**	**N**
Overall						
	-0.05	-0.1	-0.16	-0.23	-0.29	9748
Density (Population/ Square Mile)						
< 1,000	-0.06	-0.13	-0.21	-0.29	-0.35	2356
1,000 to 5,000	-0.04	-0.09	-0.15	-0.22	-0.28	3502
5,000 to 10,000	-0.04	-0.09	-0.14	-0.20	-0.26	2935
> 10,000	-0.02	-0.05	-0.08	-0.12	-0.16	955
Urban Form						
Urban Mixed Type	-0.03	-0.07	-0.11	-0.15	-0.20	2726
Other	-0.05	-0.10	-0.17	-0.24	-0.30	7022
Income (Thousand Dollars)						
0 to 40	-0.13	-0.24	-0.34	-0.42	-0.49	3246
40 to 80	-0.04	-0.10	-0.17	-0.25	-0.32	3590
80 Plus	-0.01	-0.04	-0.08	-0.13	-0.18	2912

Table 63. Fuel Price Elasticity of Non-metropolitan Household DVMT
Given 20 and 40 Per Cent Changes in Fuel Price

	10% Price Change	**20% Price Change**	**30% Price Change**	**40% Price Change**	**50% Price Change**	**N**
Overall						
	-0.03	-0.04	-0.05	-0.06	-0.06	9321
Density (Population/ Square Mile)						
< 1,000	-0.04	-0.05	-0.06	-0.06	-0.07	6217
1,000 to 5,000	-0.02	-0.02	-0.03	-0.03	-0.04	2321
5,000 to 10,000	-0.03	-0.03	-0.04	-0.04	-0.04	733
> 10,000	-0.05	-0.05	-0.05	-0.05	-0.05	50
Urban Form						
Urban Mixed Type	-0.01	-0.02	-0.02	-0.03	-0.04	89
Other	-0.03	-0.04	-0.05	-0.06	-0.06	9232
Income (Thousand Dollars)						
0 to 40	-0.08	-0.09	-0.10	-0.12	-0.13	4725
40 to 80	-0.01	-0.02	-0.02	-0.02	-0.03	3303
80 Plus	-0.01	-0.01	-0.01	-0.02	-0.02	1293

Table 64. Fuel Price Elasticity of Non-metropolitan Household DVMT
Given 100 to 500 Per Cent Changes in Fuel Price

	100% Price Change	**200% Price Change**	**300% Price Change**	**400% Price Change**	**500% Price Change**	**N**
Overall						
	-0.1	-0.2	-0.28	-0.36	-0.43	9321
Density (Population/ Square Mile)						
< 1,000	-0.12	-0.22	-0.31	-0.40	-0.46	6217
1,000 to 5,000	-0.07	-0.14	-0.22	-0.29	-0.36	2321
5,000 to 10,000	-0.07	-0.13	-0.19	-0.26	-0.32	733
> 10,000	-0.07	-0.11	-0.15	-0.20	-0.24	50
Urban Form						
Urban Mixed Type	-0.07	-0.13	-0.20	-0.27	-0.34	89
Other	-0.10	-0.20	-0.28	-0.36	-0.43	9232
Income (Thousand Dollars)						
0 to 40	-0.21	-0.34	-0.45	-0.54	-0.60	4725
40 to 80	-0.06	-0.15	-0.24	-0.33	-0.40	3303
80 Plus	-0.03	-0.07	-0.12	-0.18	-0.24	1293

A large number of studies have been done to estimate the elasticity of vehicle travel and fuel consumption to changes in fuel price. An unpublished study by Dong, Hunt and Weidner for ODOT summarizes the literature on this subject.[46] Highlights include:

- Goodwin (2004) estimated the average long run fuel price elasticity of vehicle travel to be -0.29 based on a review of 69 international studies published after 1990.
- Goodwin also found the fuel price elasticity to vehicle travel to be decreasing over time as follows:
  - Pre-1974: -0.54
  - 1974-1981: -0.32
  - Post-1981: -0.24
- de Jong and Gun (2001) estimated the average long run fuel price elasticity of vehicle travel to be -0.26 based on a review of 50 international studies published after 1985.
- Kennedy and Wallis (2007) estimated the fuel price elasticity of urban off peak car traffic after two years to be -0.36 and corresponding elasticities of urban peak and rural traffic to be -0.24 and -0.19, respectively.

The results of fuel price elasticity studies, as with other elasticity studies, depend on the study methods. Many of these studies are longitudinal studies using aggregate data. In contrast, the GreenSTEP models are based on highly disaggregate cross-sectional data. Pickrell and Schimek estimated elasticities using a cross-sectional model based on 1995 NPTS data. Depending on the model structure, they estimated elasticity values in the range of -0.19 to -0.32.[47]

More recent longitudinal studies (after 2001) of the fuel price elasticity of fuel consumption and VMT estimated much lower short run elasticities than previously. Hughes, Knittel and Sperling estimated the short-range fuel price elasticities of fuel consumption to range from -0.034 to -0.077 from 2001-2006.[48] The U.S. Congressional Budget Office (CBO) estimated that a 10 per cent increase in fuel price reduced VMT by 0.2 to 0.3 percent in the short run and 1.1 to 1.5 percent in the long run.[49] Small and Van Dender, estimated short run fuel price elasticity of -0.02 to -0.03 and a long run elasticity of -0.11 to -0.15.[50]

These more recent findings are consistent with the findings in the earlier section on the household budget approach to modeling the effects of prices in GreenSTEP.

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[46] Dong, Hongwei, et al, 2010.
[47] Pickrell, Don and Paul Schimek, 1998,. p. 32.
[48] Hughes, Jonathan E. et al, 2008, pp. 93-114.
[49] U.S. Congressional Budget Office, 2008.
[50] U.S. Department of Transportation, “Transportation’s Role in Reducing U.S. Greenhouse Gas Emissions, Volume 1: Synthesis Report”, Report to Congress, April 2010, p. 3-15.

Fuel Economy Sensitivity

The elasticities of DVMT and fuel consumption with respect to fuel economy for metropolitan and non-metropolitan area households are shown in Table 68 and Table 69 respectively. The magnitude of the fuel consumption elasticity is dependent on the travel rebound effect that occurs because the cost of travel is reduced. Since the effect of cost on travel depends on the magnitude of the cost, elasticities were calculated at base year (2001) fuel prices and at 4 times the base year prices.

Table 65. Fuel Economy Elasticity of Metropolitan Household DVMT
10% to 50% Increases in Fuel Economy

	10% MPG Change	**20% MPG Change**	**30% MPG Change**	**40% MPG Change**	**50% MPG Change**
Base Gas Price					
DVMT	0.01	0.01	0.01	0	0
Fuel	-0.99	-0.99	-0.99	-0.99	-0.99
4 X Base Price					
DVMT	0.37	0.35	0.32	0.31	0.29
Fuel	-0.61	-0.64	-0.66	-0.68	-0.7

Table 66. Fuel Economy Elasticity of Non-metropolitan Household DVMT
10% to 50% Increases in Fuel Economy

	10% MPG Change	**20% MPG Change**	**30% MPG Change**	**40% MPG Change**	**50% MPG Change**
Base Gas Price					
DVMT	0.02	0.02	0.02	0.02	0.02
Fuel	-0.97	-0.98	-0.98	-0.98	-0.98
4 X Base Price					
DVMT	0.55	0.53	0.5	0.48	0.46
Fuel	-0.43	-0.46	-0.48	-0.51	-0.53

It can be seen that at base year fuel prices, the effects of improvements to fuel economy are predicted to have minimal effects on household vehicle travel. Almost all of the improvements would go into reduced fuel consumption. This is consistent with the observation that fuel prices had minimal effects on vehicle travel in the recent past.

As expected, the rebound effect is much greater at 4 times the base year fuel cost. A 50% increase in average fuel economy would result in a 14.5% increase in VMT in metropolitan areas and a 23% increase in non-metropolitan areas. The greater fuel economy elasticity of fuel consumption at higher fuel prices is a direct consequence to budget model approach. This approach is also responsible for the decline in estimated elasticities as the magnitude of the fuel economy improvement increases. The fuel economy elasticity is greater for non-metropolitan households than metropolitan households because the fuel price elasticity for non-metropolitan households is greater as well.