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Internalizing Congestion and Environmental Externalities with Green Transportation Financing Policies

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Abstract

With the declining purchasing power of the gas tax the U.S. Federal Highway Trust Fund has experienced shortfalls in revenue despite increasing transportation infrastructure maintenance and investment needs.(*1*) This paper develops three green transportation financing polices based on the fixed vehicle mileage traveled (VMT) fee concept (*2*), and analyzes their impact on revenue generation, congestion management, energy/environmental sustainability, and equity at the national and state levels in the U.S. One policy is a green VMT fee that is linked to vehicle fuel economy, the second a mileage-based emissions tax correlated with vehicle greenhouse gas (GHG) and pollution emission ratings, and the third a variable VMT fee based on regional congestion levels. A demand model with vehicle miles traveled as the dependent variable is developed for the analysis. The green transportation financing options are compared against a base-case policy defined as a 10-cent/gallon increase in the Federal gas tax. To gauge policy effectiveness, we measure changes in total Federal and State revenue, VMT, fuel consumption, pollution emissions, and welfare by various demographic groups., Under all policy scenarios, total vehicle miles traveled and consumer surplus decrease with lowest-income (<$25,000/year) households showing the largest percent reduction if no compensatory schemes are employed. The distributional impact of the proposed green transportation financing policies is similar to that of the existing gas tax, with green VMT fees and emissions taxes being relatively more regressive, and nation-wide congestion pricing being relatively more progressive.

Acknowledgement

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1. Introduction

Recent research has explored various policy options to address the shortfall in gas tax revenue,(*3,4,5)* from fixed distance-based user fees to variable fees linked to vehicle fuel economy, emissions (*6,7,8*) or local congestion levels.(*9,10)* Many argue against a fixed vehicle miles traveled (VMT) fee because it penalizes those who have purchased high efficiency vehicles.(*11*) Variable VMT fees are superior in theory because they can incorporate various externalities (*12,13*) of driving and consequently improve social welfare. Some caution that variable per mile fees should be properly designed or they may not provide sufficient incentives to encourage the purchase of environmentally friendly vehicles.(*14,26)*

Transportation experts generally agree that today's petroleum based motor vehicle highway system is unsustainable (*15*,*16*) due to air quality issues, climate change concerns, congestion and urban sprawl. Growing energy consumption and pollution in the transportation sector has a distinct spatial and urban dimension. (*17,18*) As urban dwellers acquire more wealth and transportation costs remain low, many households move to the periphery of urban areas, increasing the frequency and distance of car trips. Transportation is one of the leading sources (33.7%) of energy-related greenhouse gas emissions in the United States. (*19*) In order to achieve sustainability, improvements will be needed in technology, land use planning and financing. (*20*) Current transportation financing practices, largely based on fuel taxes and vehicle registration fees, do not account for the external costs a driver imposes on the environment or other road users. Optimal first-best pricing to address congestion and environmental externalities is difficult to implement because of its lack of public and political support. (*21,22,23)* Suggested second best pricing schemes include green distance-based user fees, emission taxes, cap and trade, and congestion pricing on selected facilities. (*24,25*)

The goal of this paper is to design and estimate the impact of several innovative green transportation financing policies based on the distance-based user charge concept, (*26,27*) including a green VMT fee based on vehicle fuel efficiency, a distance-based emissions tax, and a mileage-based congestion pricing scheme. These financing options are not proposed to necessarily maximize system-wide social welfare. Instead, the vision is to design practical and feasible financing schemes that (a) can be implemented with a nation-wide or state-wide distance-base user charge system; (*28,29*) (b) meet pre-determined revenue generation goals; (c) significantly improve transportation system efficiency and sustainability by internalizing congestion and environmental externalities; and (d) produce distributional effects that are either acceptable or can be addressed with readily-available policy tools.

Our methodology employs a regression-based demand model that estimates the heterogeneous elasticity of VMT for different population groups in response to the proposed green transportation financing policies. (*30*) The impacts of these policies with regard to revenue generation, VMT, congestion, sustainability, and equity are then evaluated based on model outputs at the national and state levels. (*31*) Distributional effects are measured for each population group (defined by income, geographical location, ethnicity, etc.) as changes in consumer surplus (*32*,*33*), VMT, gasoline consumption, total revenue collected by federal and state agencies, and overall welfare changes. It is the authors' hope that with an improved understanding on the effectiveness and equity of transportation financing options, informed decisions can be made toward a green and sustainable transportation system. (*34*)

2. Background and Literature Review

In 1970, the Environmental Protection Agency was given responsibility to regulate motor vehicle pollution and mandated a 90 percent reduction in the emissions of new automobiles. In 1994 the phase-in began for cleaner vehicle standards and technologies required by the 1990 Clean Air Act. According to the EPA, about 20 percent of total CO_2 emissions come from passenger vehicles (*19*). The Congressional Budget Office analyzed policy options that address greenhouse gases and found that carbon taxes, cap-and-trade legislation and a gas tax increase would result in similar declines in GHGs. (*35,36)* Others suggested policies to lower emissions include providing incentives for newer vehicles, alternative fuel vehicles and hybrids,(*37*) increased emission standards and investment in advanced technology. (*38*) Most transportation related criteria pollutants (PM_{10}, $PM_{2.5}$, VOCs, CO, NO_x and SO_2) have declined since 1990, but carbon dioxide has been on the rise. The transportation sector produced 2.0 billion metric tons of CO_2 equivalent GHGs in 2006 and has grown at a rate of 1.4 percent since 1990. A suggested price of $28 per metric ton of CO_2 emitted would add about 25 cents to the price of a gallon of gasoline. In the short run, CO_2 levels would remain the same but over time would show a 2.5% decline, a relatively small drop due to the low price elasticity of gasoline and the car dependent nature of Americans. Though politicians assume there is much opposition to increased gas taxes, a Mineta Transportation Institute survey of California residents showed that the majority of respondents supported green policies like incentives for less polluting cars, green mileage fees and green vehicle registration.(*39*) Most studies have found, however, that emissions regulations are regressive in nature and the environmental risks disproportionately affect poorer groups. (*40,41,42)*

Reducing vehicle miles traveled not only results in lowered emissions but also lower congestion levels. (*43*) Many urban areas need stronger pricing strategies to reduce the congestion (*44*) from passenger vehicle use. Most vehicle owners prefer to use personal vehicles to travel since most of the costs are already paid for i.e. ownership, registration, and insurance. With a significant price signal, road users will likely start to reconsider their trip decisions. Urban areas like San Diego, Los Angeles and London have successfully implemented pricing schemes that have reduced vehicle miles driven. (*45,46,47)* Congestion pricing can provide more reliable trip times, better system performance, and substantial revenue gains. (*48,49)* While this paper will explore a nation-wide congestion pricing scheme based on regional congestion levels, vehicles could also be priced based on specific roads, time of day or vehicle occupancy. (*50*) Other alternatives include a ‘cash out’ approach to reward those who reduce their vehicle use. (*51*) Some argue that congestion pricing is unjust and tends to penalize lower-income drivers. (*52*) However, the distributional effects of a nation-wide congestion pricing scheme has not been thoroughly studied.

This brief review reveals that the key externalities of driving not yet internalized include congestion, pollution emissions, and GHG emissions, which will be addressed in our analysis. Externality due to traffic accidents is partially internalized with user-pay auto insurance programs. (*53,54,55)* Previous research has extensively discussed distance-based insurance charge. (*56*)

3. Data and Model

A multiple regression model is developed with household annual miles driven as the dependent variable. The regression model can estimate the overall impact of proposed green transportation financing policies (detailed in Section 4) based on a variety of measures of effectiveness (detailed in Section 5). The policy shift from the existing gasoline tax to distance-based user fees is captured in the "fuel cost per mile" variable in our model. Under the gasoline tax, the fuel cost per mile is calculated as the price of gasoline divided by a vehicle's fuel efficiency. Under the per mile user fees, the gasoline tax is subtracted out and the per-mile charge is added to the total. Our model also employs interaction variables between fuel cost per mile and other socio-demographic variables to allow for heterogeneous demand responses by different population groups. There are 20 independent variables in the model, and the dependent variable is the natural log of annual vehicle miles driven at the household level.

The multiple-regression model is specified as follows:

$$M = f\,(P_M, I, SUB, V, L, P_M{*}I, P_M{*}SUB, HH_M) \qquad (1)$$

Where M is total annual household miles; P_M is fuel cost per mile; I is annual household income; and V is the number of household vehicles. The fuel cost per mile variable is a weighted average based on the miles reported for each vehicle a household owns. *SUB*, a dummy variable, is equal to 1 if a household has more than one type of vehicle (e.g. a car and an SUV). As the fuel cost per mile changes for each vehicle, a household with multiple vehicle types will be able to substitute driving between different vehicle types. L is a vector of 3 dummy variables that represents Census Metropolitan Statistical Area Categories (Category 1: large urban area with rail transit; 2: large urban area without rail transit; and 3: small urban area). $P_M{*}I$ is an interaction term between household income and fuel cost per mile, which allows for different income groups to respond differently to changes in fuel cost including gas tax or VMT fees. $P_M{*}SUB$ is another interaction term that allows for households with or without multiple vehicle types to respond differently to fuel cost changes. HH_M is a vector of other household characteristics, including number of children, number of workers, number of licensed drivers, age, ethnicity, and gender of the household head, land use density, and transit use. The fuel cost per mile coefficient is expected to be negative, consistent with a downward sloping demand curve for vehicle miles driven. If a household owns more vehicles, it is expected that the household will drive more miles. Households with many types of vehicles are likely to drive more than households that are not able to substitute between vehicles; the *SUB* coefficient is expected to be positive. As the number of children or workers in the household increase, the household is also expected to drive more miles.

To estimate the model, we use the 2001 National Household Travel Survey (NHTS) data with a final sample of 15,902 households from all 50 states and Washington D.C. The household samples are selected based on the completeness and accuracy of survey responses. Additional information necessary for model estimation such as fuel price is obtained from the Energy Information Administration (EIA). Table 1 shows the results from the multiple regression model and explains all model variables in detail. The R-squared value for the model is 0.7116, and the adjusted R-squared value 0.7113.

The regression results suggest that as fuel costs rise, households will lower their annual miles driven. Households with more vehicles, workers, and children tend to drive more. Households with a male head drive more than those with a female head. The household demand elasticities (*57*) with respect to fuel costs changes due to financing policy can be computed from the coefficients of fuel cost per mile and the interaction variables. According to the model, the lowest-income households with only one vehicle have the largest sensitivity to policy changes, and would drive almost 1.8% less in response to just 1% increase in fuel cost. The driving behavior of the richest households with multiple vehicle types would not be impacted at all with elasticity close to zero. Some high income households could experience a positive elasticity in response to less congested road conditions due to the overall reduced demand for driving. Figure 1 plots the distribution of demand elasticities of all households in our sample. The average elasticity is about 0.32, which indicates that if a new financing policy doubles the user-paid cost of driving, total VMT would decrease by 32% for the average household.

This regression-based demand model enables us to compute the changes in VMT, taxes paid, and welfare at the household level in response to green transportation financing policies, which supports the distributional impact analysis. The household-level results are then aggregated to the national and state levels for revenue and welfare analysis in the following sections.

4. Green Transportation Financing Policies

A common revenue-generation objective should be established first for the design and comparison of green transportation financing policies. The 2009 National Surface Transportation Infrastructure Financing Commission has recommended a 10 cents/gallon increase to the existing 18.4 cents/gallon federal gas tax. Though states would likely increase their own individual state gas taxes, to simplify our analysis we chose to measure the effects of only a federal tax increase. With the demand model developed in Section 3, we estimate that this 54.3 percent increase in tax rate would increase total tax revenue by 50.5 percent while decreasing total VMT by 2.5 percent. All three green transportation financing policies presented below are designed to produce the same amount of total revenue as a 28.4 cents/gallon federal gas tax. According to previous research, (*58*) a flat VMT fee of 1 cent/mile results is roughly revenue neutral to the present gas tax. Since the proposed polices are all variable distance-based user charges, we also fix the base (minimum) per-mile fee rate at 1 cent/mile for all policy scenarios. This section also demonstrates how demand models can be used to design transportation financing policies under a specific revenue goal.

Green VMT Fee

The first policy charges two different VMT fee rates based on vehicle fuel efficiency, which is directly related to fuel consumption and GHG emissions. 20 mpg (the mean fuel efficiency of today’s passenger vehicle fleet) is set as the threshold value. If a vehicle has fuel efficiency greater than or equal to 20 mpg, the base VMT fee of 1 cent/mile will be assessed. The demand model is employed to compute the VMT fee rate that must be assessed on vehicles with <20mpg fuel efficiency in order to achieve the same 50.5% revenue increase, which turns out to be 2.1 cents/mile.

Emission Tax

The third policy targets environmental externalities and considers pollution emissions and GHG emissions. Under this mileage-based emission tax, the base rate of 1 cent/mile is first charged on all users. A mark-up emission charge is then computed based on the vehicle emission ratings. The emission ratings are based on three factors: vintage, vehicle type (a proxy for engine size), and fuel efficiency (for GHG considerations). The final emission rating for a vehicle is the sum of the vintage, vehicle type, and fuel efficiency scores, and ranges from 0 to 15. Again, linear interpolation methods are used to determine the markup per mile fees for all vehicles. To generate the same revenue as the above policies, the highest markup fee rate should be 1.3 cents/mile, making the highest total VMT fee rate 2.3 cents/mile. For instance, a brand new Honda Civic will have a rating of 1 and be charged 1.08 cents/mile under this emission tax policy, and a ten-year old Ford F-150 will have a rating of 9, and be charged 1.78 cents/mile.

Emission Rating Scoring System

Vintage (age)	Score
>=30	6
25~29	5
20~24	4
15~19	3
10~14	2
5~9	1
<5	0

Vehicle Type	Score
Motorcycle	0
Car/station wagon	1
Passenger Van	2
SUV	2
Pickup truck	2
Other truck	3

Fuel Efficiency (MPG)	Score
< 10	6
10~14	5
15~19	4
20~24	3
25~29	2
30~34	1
>=35	0

Congestion Pricing

The second policy represents a nation-wide congestion pricing scheme. It charges road users living in areas with no or minimum congestion the base VMT fee rate of 1 cent/mile. Road users living in areas with higher levels of congestion will be charged per mile taxes that result in higher VMT fees. Congestion in urbanized areas is measured by the travel time indices (TTI) from the Texas Transportation Institute Urban Mobility Report. (*59*) Without more specific local and corridor data, we assumed away the variance in corridor-level congestion within each metropolitan statistical area. Congestion in rural areas is assumed to be nonexistent, and therefore the base VMT fee rate applies to all rural areas. The TTIs measure the ratios of travel time during the peak period to free-flow travel time in all urbanized areas in the U.S. and range from 1 to 1.83 with 1.83 representing the highest level of congestion. The VMT fee rates in urban areas are positively correlated with their travel time indices. Linear interpolation methods are adopted, which implies that an area with a Travel Time Index of 1.415 (halfway between 1 and 1.83) will incur a VMT fee rate halfway between the base rate and the highest rate. Based on demand model outputs, it is computed that the highest VMT fee rate needs to be 3.4 cents/mile for this congestion pricing policy to generate the same revenue as the 28.4 cents/gallon federal gas tax. In other words, those living in the most congested city, Los Angeles (highest travel time index = 1.83) area will be charged 3.4 cents/mile under this policy, which is about three times of what drivers in Los Angeles pay for driving right now. Those living in San Francisco, Washington DC, Chicago, Houston, Boston, and other congested urban areas will be charged VMT fee rates slightly lower than 3.4 cents/mile because the most congested cities will be penalized the most under a nation-wide congestion pricing scheme.

5. Measures of Policy Effectiveness

In order to evaluate the effectiveness of the proposed green transportation financing policies with the VMT demand model, a number of performance measures are developed in this section and presented below.

Notation

M	Annual Household Miles Driven
P	Per Mile Tax/Fee rate
AFE	Average Household Fuel Efficiency
G	State Gas Tax per gallon
HTF	Highway Trust Fund collected from proposed green transportation financing policies
Green	Subscript indicating values under proposed green transportation financing policies
Current	Subscript indicating values under current 18.4 cents/gallon federal gas tax
H	Index of all household in our sample
S	Index of States in the U.S.

Performance Measures

Total Federal Revenue $\Sigma_H[P*M_{Green}]/.00015$, 0.00015 is the ratio of total

	households in our sample to total households in the U.S..
State Gas Tax Revenue	$\Sigma_S\ [M_{S,Green}*G/(AFE)]/$% of households from state S represented in our sample
HTF Reimbursement	Total Federal Revenue Collected from State S * HTF Repayment Ratio based on Existing Funding Formula
Total State Revenue	State Gas Tax Revenue + HTF Reimbursement
VMT Reduction by Household	$(M_{Green} - M_{Current})/M_{Current}$
VMT Reduction by Group	$(\Sigma_H M_{Green} - \Sigma_H M_{Current})/\Sigma_H M_{Current}$ for each population group
Gasoline Consumption	M/AFE
Federal Taxes Paid by Household	$(M_{Green})*(P)$
Total Taxes Paid by Household	$(M_{Green})*(P + G_{state}/AFE)$
Change in Consumer Surplus	$0.5(M_{Green}+M_{Current})(P_{Current} - P_{Green})$, Rule-of-Half Method
Change in Welfare	Change in Consumer Surplus + Taxes Paid

6. Results

6.1. Impact on Federal and State Transportation Revenues

By design, all three green financing policies will generate the same amount of total federal revenue that is 50.5% higher than what is generated by the current 18.4 cents/gallon federal gas tax. This is a sizable increase of revenue for the Highway Trust Fund (HTF). With the reallocation of the HTF to individual states based on current funding formulas, (*60*) states should benefit from the proposed green financing policies with increased payment from the federal HTF even if the state tax remains constant. The funds are apportioned with a complex arithmetic tool by the Federal Highway Administration to states in 13 funding categories including the National Highway System and Interstate Maintenance. The increase of federal transportation taxes paid also implies a reduction in VMT, which reduces state gas tax revenues (assuming state gas tax rates do not change). The actual impact of the proposed green policies on total transportation revenue for a particular state also depends on the donor/donee status of the state, and the nature of the green financing policy. After all these factors are considered, the percentage change in total transportation revenue for each state is computed and illustrated in Figures 2 a~c for all three proposed policy scenarios. In general, the green VMT fee and the emission tax have similar effects on state revenues, because both policies attempt to internalize environmental externalities with slightly different methods. Though all states experience revenue gains under these two policies, rural states like Alaska, Nevada, South Dakota, and Wyoming benefit the most because they tend to have vehicle fleets with high percentages of fuel-inefficient, older, and larger vehicles. This is because households in these states will pay much higher per-mile taxes, which results in higher tax revenue contributions to the federal HTF and consequently higher state reimbursements after HTF reallocation. For the same reason, states with large congested cities including California, Illinois, Maryland, New Jersey, and Massachusetts have the most revenue to gain with congestion pricing, while rural states such as those in the upper Midwest experience shortfalls in revenue as shown by the light colored states in Figure 2c.

6.2. Impact on Vehicle Miles Traveled

Since all three proposed policies impose a higher cost of driving to almost all households, VMT is expected to decrease accordingly. For the average household, the per-mile cost of driving increases by approximately 12%. Results show that the total national VMT decreases by 2.57% under the green VMT fee, 2.76% under congestion pricing, and 2.93% under emission tax. The actual percentage reductions in fuel consumption and emissions are both larger since these policies penalize the use of fuel-inefficient vehicles and driving in congested conditions. We will estimate the actual sustainability impact with fuel consumption and emission models in our future research. The nation-wide congestion pricing scheme has quite different VMT impact in different states (see Figure 3). In states with the highest levels of congestion including California, Maryland, Massachusetts, and New Jersey, VMT decreases by more than 6%. It is important to note that once the federal fuel tax were to switch to a distance based mechanism, states would likely switch to distance based state gas taxes in the ensuing 5-7 years. Based on previous research that compares the gas tax to a flat VMT fee, we can conclude that a complete switch to distance based fees at both the state and federal levels would likely result in even further declines in vehicle miles traveled. A revenue neutral switch to a flat federal VMT fee at the present revenue level resulted in some rural regions actually showing an increase in miles traveled. The distribution of change across different states showed an average overall decrease in miles traveled. When the federal tax was raised, all states showed a decrease in miles traveled. Households with low efficiency vehicles would find driving more inexpensive with a VMT fee and would likely be the households least affected by a change to a distance based user fee that was not linked to vehicle fuel efficiency or congestion levels.

6.3. Distributional Impact by Income, Geographical Location, Ethnicity, and Age Groups

Results on distributional effects of the green transportation financing policies are presented both numerically and graphically. While some readers may find the numerical results in the tables a bit overwhelming, they are intended to provide additional details and supplement the summary results in the figures.

Under all policy scenarios, household total VMT decreases with low-income households showing the largest percent reduction as shown in Figure 4a and Tables 2a~c. Low income households have a greater sensitivity to price increases, and any increase in tax payments would represent a greater percentage of their income. The tax increases analyzed in this paper are not a great enough price signal however to significantly affect the driving decisions of high income households. The model also shows that lower income groups experience the greatest reduction in consumer surplus under the emission tax scheme (Figure 4b). This is likely due to the fact that lower income households are less likely to own newer, more fuel efficient vehicles and so will be taxed at higher VMT fee rates under the Green VMT and Emission Tax policies. Affluent households tend to be charged less under fees linked to vehicle fuel efficiency and emissions because they can more easily afford newer vehicles. Our data shows that about 30 percent of the lowest income group own vehicles with average fuel efficiencies less than or equal to 18 miles per gallon while only about 24 percent of the highest income group fall into this category. Based on the consumer surplus findings, all three green financing policies are equitable for households with more than $25,000 annual income. The overall impact on these households (converted to a monetary value and measured as a percentage of income in Figure 4b) is about the same. The households making less than $25,000 a year need to be compensated, possibly in the form of a transportation tax credit.

It is interesting to observe that the congestion pricing policy, when implemented at the national level, is the least regressive of all policies analyzed including the existing gas tax. This is because households in congested urban areas tend to earn more income than those living in uncongested areas. Another key factor is that in urban areas there tends to be more public transit alternatives and the urban poor disproportionately tend to use public transit. The regional analysis in this paper focuses on the average household in each region and therefore does not consider distributional effects among households within the same Census region. We further analyze the distributional impact by income group. Under congestion pricing, higher-income households also pay significantly more federal transportation taxes as a percentage of income compared to what they are paying now (Figure 4c). The percent increase in federal tax contribution is similar across most income groups for the emission tax and the green VMT fee with low income groups again being most negatively affected by the emission tax.

Based on transportation taxes paid, rural households unsurprisingly benefit more from the congestion pricing scheme than urban households. It should be noted that urban households paying higher congestion-based VMT fees should also benefit from reduced levels of congestion, which is not considered in our analysis. In contrast, the emission tax and the green VMT fee both cause a greater reduction in consumer surplus for rural households (Figure 5a, Tables 3a~c), because rural households own higher shares of older, larger, and fuel inefficient vehicles. Our data shows that 31.3 percent of rural households own vehicles with fuel efficiencies of 18 miles per gallon or less while only 21.6 percent of MSA 1 households fall into this category. Another possible explanation for decreased consumer surplus could be that rural drivers have a greater tendency to drive at very high speeds due to the very low traffic flows and so burn gas more inefficiently, though this effect cannot be captured by our model. The Green VMT fee and the Emissions Tax affect the West South Central and East South Central regions of the U.S. most negatively. The Pacific and New England regions show the lowest reduction in aggregate welfare associated with each subgroup under these environmentally friendly policies. More affluent regions are not as price sensitive to changes in revenue policies, tend to drive more (i.e. generate more federal revenue) and also tend to have better developed transit options. Congestion pricing has a somewhat opposite effect reducing the aggregate welfare associated with each subgroup, most drastically for the Pacific and New England regions. The West North Central and East South Central regions see the lowest change in aggregate welfare associated with each subgroup.

Our analysis of distributional effects by ethnic groups (Figure 5b, Tables 3a-c) indicates that Asians and Hispanics are more negatively affected by congestion pricing possibly because higher percentages of these two ethnic groups reside in large congested urban areas. According to our data about 39 percent of Hispanics and 46 percent of Asians live in large urban areas with rail while 7 and 13 percent respectively live in rural regions. The green VMT fee and emission tax most negatively affect Hispanics and Whites, but not to a significant degree. Figure 5c shows the impacts by age group. All policies seem to impact the younger population groups more than the 64+ group. The elderly population drives much less and thus impacted less by increases in per-mile driving costs.

7. Conclusion

Recent debates and studies in the U.S. on distance-based use charge and vehicle mileage fees are largely driven by interests in a more sustainable funding stream for financing the surface transportation system. (*61,62*) Pilot tests on VMT fee technology and implementation have also been recently conducted at the state and national levels. (*63,64*) Many researchers and practitioners have also recognized and promoted the possibility of internalizing the congestion and environmental externalities of driving with variable VMT fees. (*65*) This paper builds on this recognition, develops theoretically sound and practically feasible green transportation financing policies based on the variable VMT fee concept, and analyzes the impact of the proposed policies on revenue, VMT, sustainability, and equity at the national and state levels. The policies designed and evaluated include a green VMT fee linked to fuel efficiency, an emission tax targeting pollution and GHG emissions, and a nation-wide congestion pricing scheme.

Reasonable variable VMT fee structures can be designed to achieve pre-determined revenue goals, such as those proposed by recent Congressional Commissions on transportation financing. With the same base rate of 1 cent per mile, the highest VMT fee rates, under the three green transportation financing policies, are 2.1, 3.4, and 2.3 cents per mile respectively, which are significantly lower than per mile charges on existing congestion pricing facilities. Green transportation financing policies can have quite different impacts on state transportation revenues, which are practical issues that need to be addressed with either changes in the HTF reallocation formulas or other revenue redistribution mechanisms. The VMT reduction effects of the proposed green transportation financing polices are moderate on average (about 2~3% reduction), though the reduction in fuel consumption and vehicle emission should be significantly larger. More aggressive policies that impose higher penalties on congestion and environmental externalities can produce even more significant benefits.

Overall, the distributional impact of green transportation financing policies is similar to that of the existing gas tax. (*66*) Households with income higher than $25,000/year are about equally affected by these policies. Households with income lower than $25,000/year are hurt more and should be compensated. Policies internalizing congestion externalities tend to hurt urban residents more, while policies internalizing environmental externalities tend to hurt rural residents more. This suggests a comprehensive policy targeting both types of externalities may be designed with similar impact on urban and rural households. Congestion pricing, implemented at the national level, is actually more progressive than the current gas tax and other green financing policies, because households in congested areas on average earn significantly higher income than their counterparts in uncongested areas. Low-income households in large congested urban areas are the biggest losers under this financing scheme. Our analysis focuses on tax incidence and does not provide a full analysis of the benefits of our policies. For example though rural regions pay less under a congestion pricing scheme, they also receive fewer benefits towards their infrastructure from the lower HTF reimbursement. Also, improved air quality from lowered VMT could result in lower expenses towards pollution mitigation. (*67*) A full analysis would require taking all factors, both costs and benefits, into consideration. Another analysis might look at different revenue allocation methods that better represent the policies which are enacted. A Green VMT fee designed to address global climate concerns should have a nation-wide reallocation system while congestion pricing and emissions taxes a more localized revenue redistribution scheme. The revenue generated in a given region for these policies should be reallocated more heavily in that region so the targeted problems of congestion or pollution can be addressed. Some urban areas are more adversely affected by certain emissions, and so policy makers may be justified in charging higher emissions taxes in urban areas over rural regions. (*68*)

Green transportation financing policies based on variable VMT fees should also influence vehicle ownership decisions, as recent empirical evidence clearly show households base their vehicle purchasing decisions on fuel costs. (*69,70,71,72,73)* Future research should extend the demand model in this paper consider both vehicle ownership and use sensitivities to green transportation financing policies. Detailed fuel consumption and emission estimation models should also be employed to quantify their benefits in terms of energy conservation, air quality improvement, and GHG emission (*74*) reduction.

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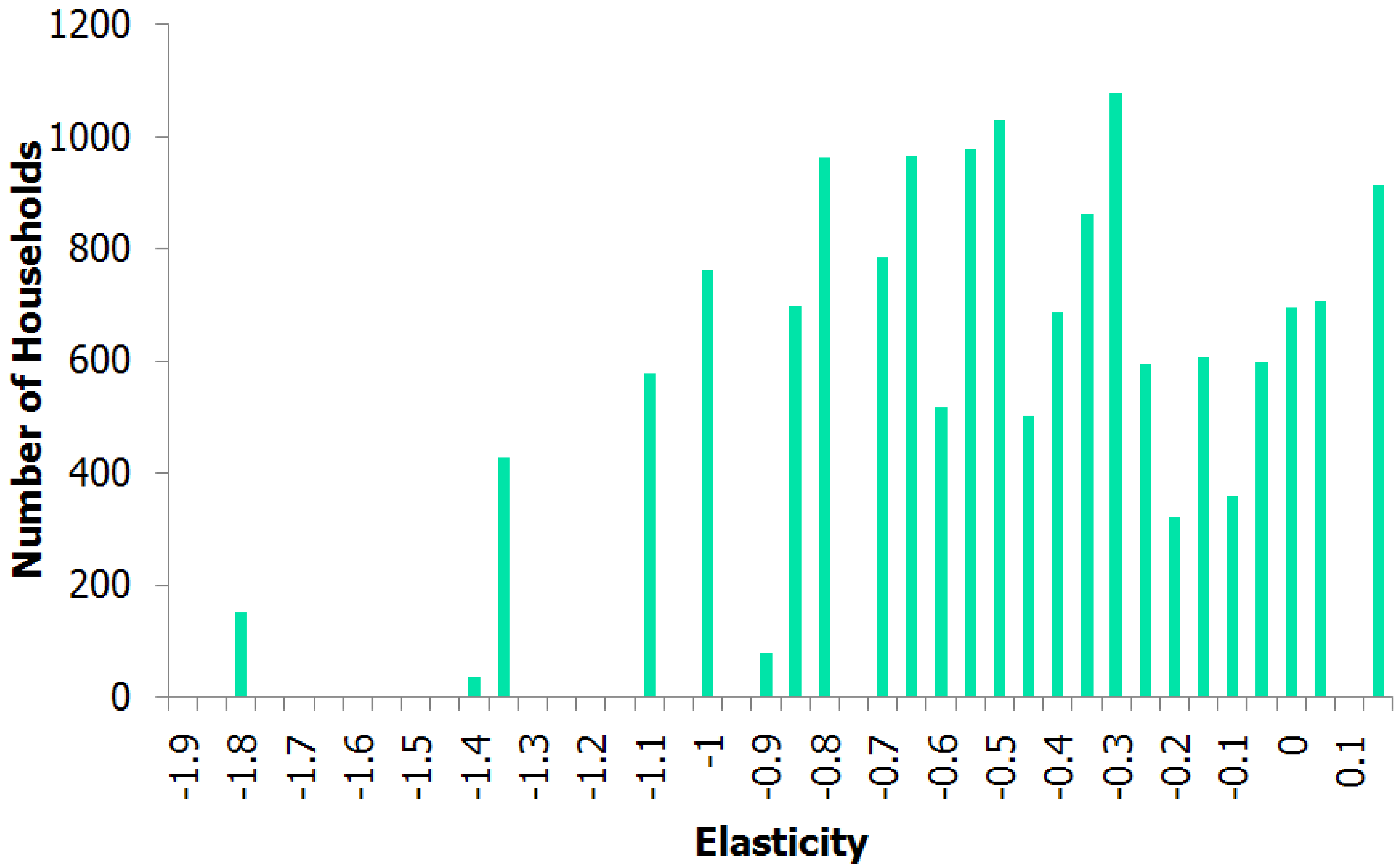
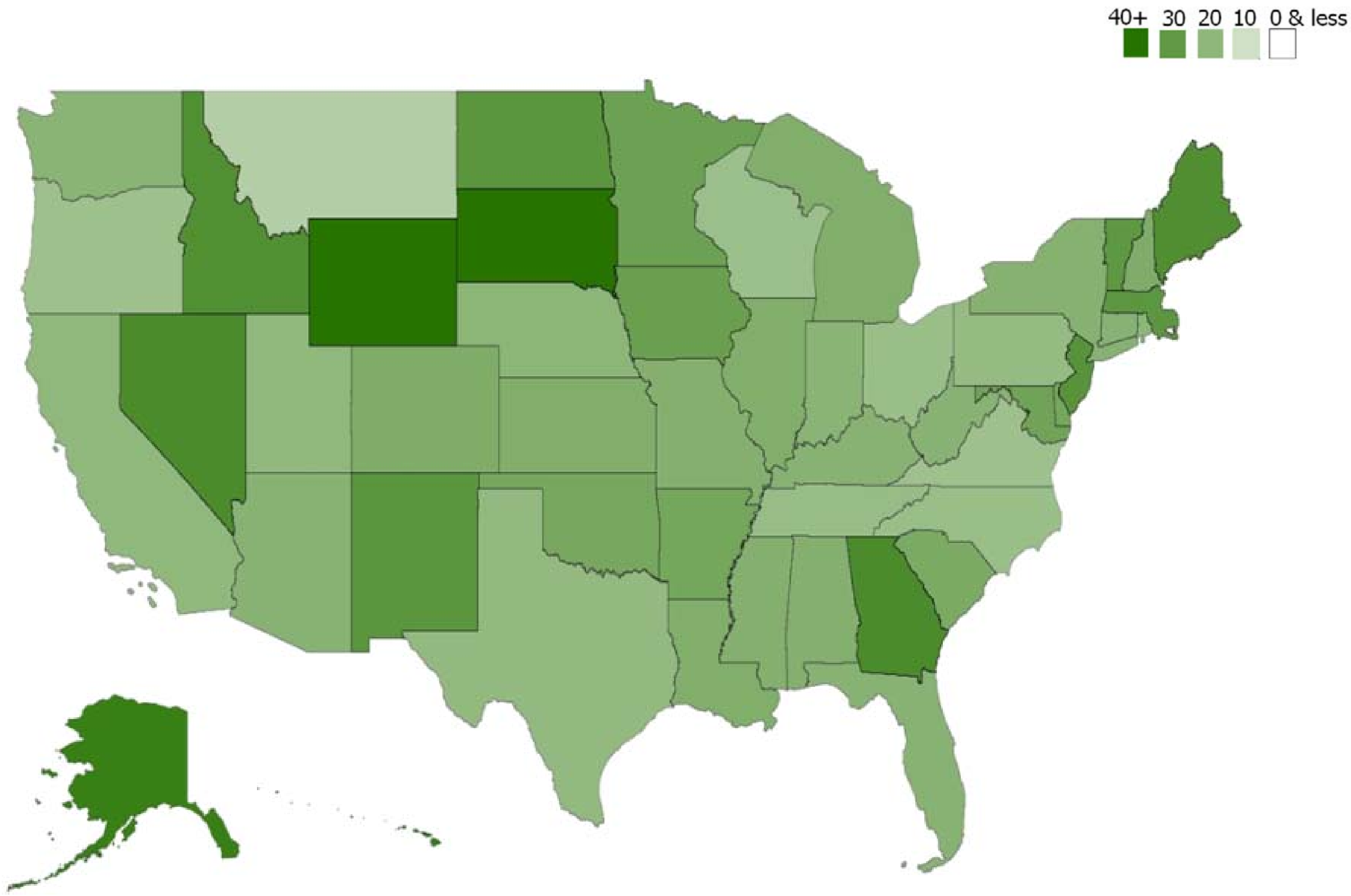
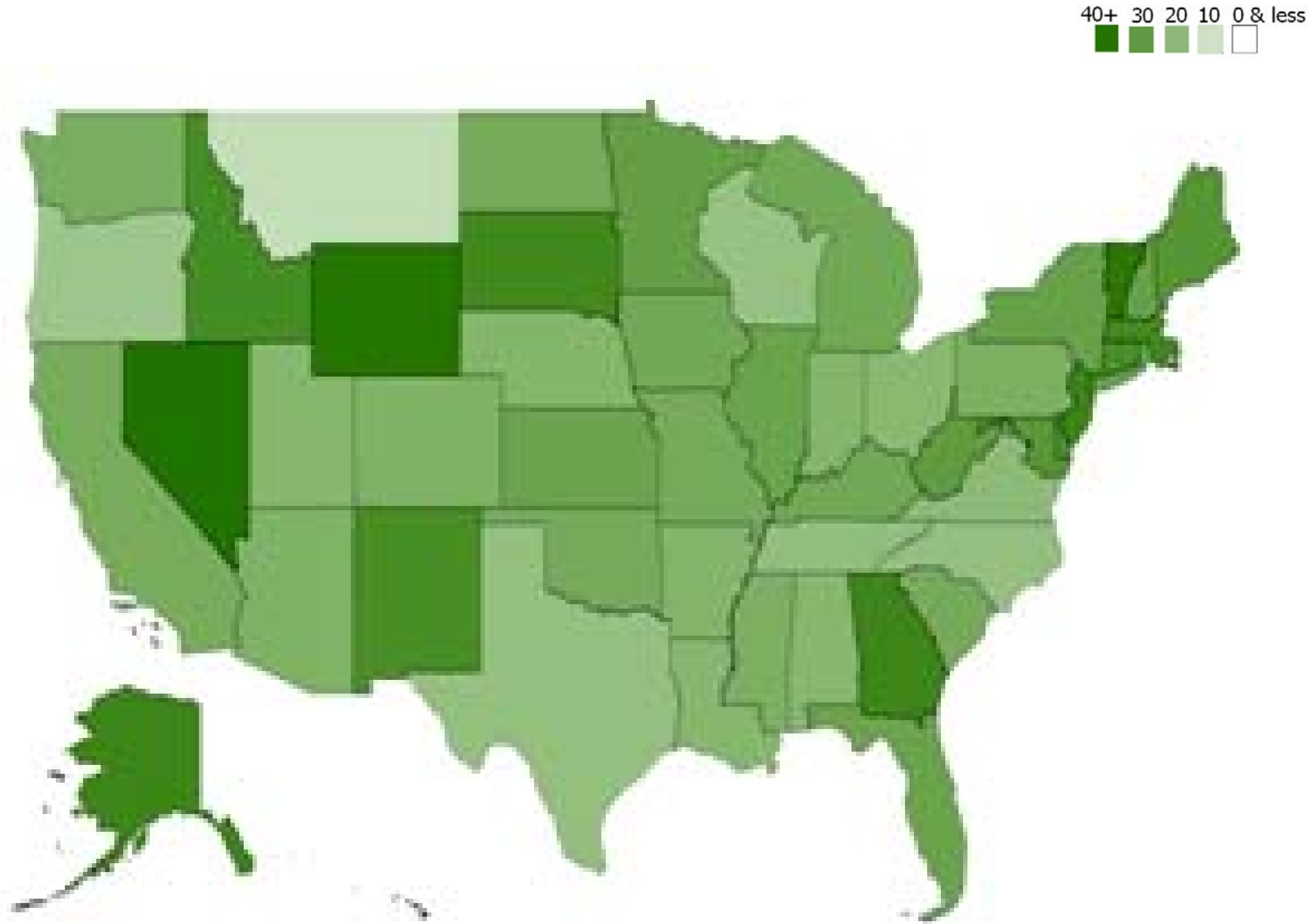


Figure 1.Distribution of Household Demand Elasticity: VMT w.r.t. Driving Cost/Mile

Figure 2. Percent Change in State Transportation Revenue from Green Financing Policies



a.Green VMT Fee



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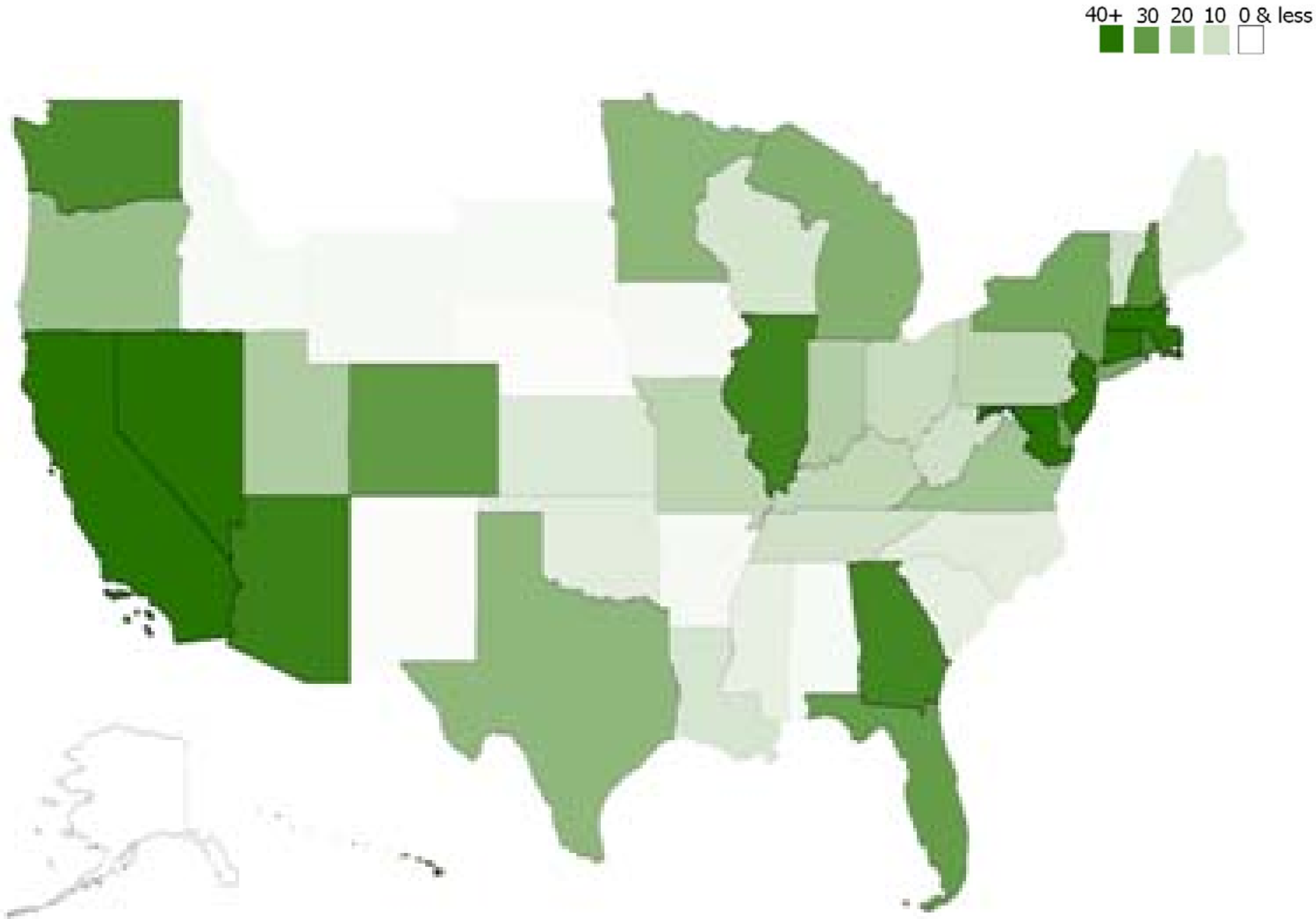


c. Congestion Pricing

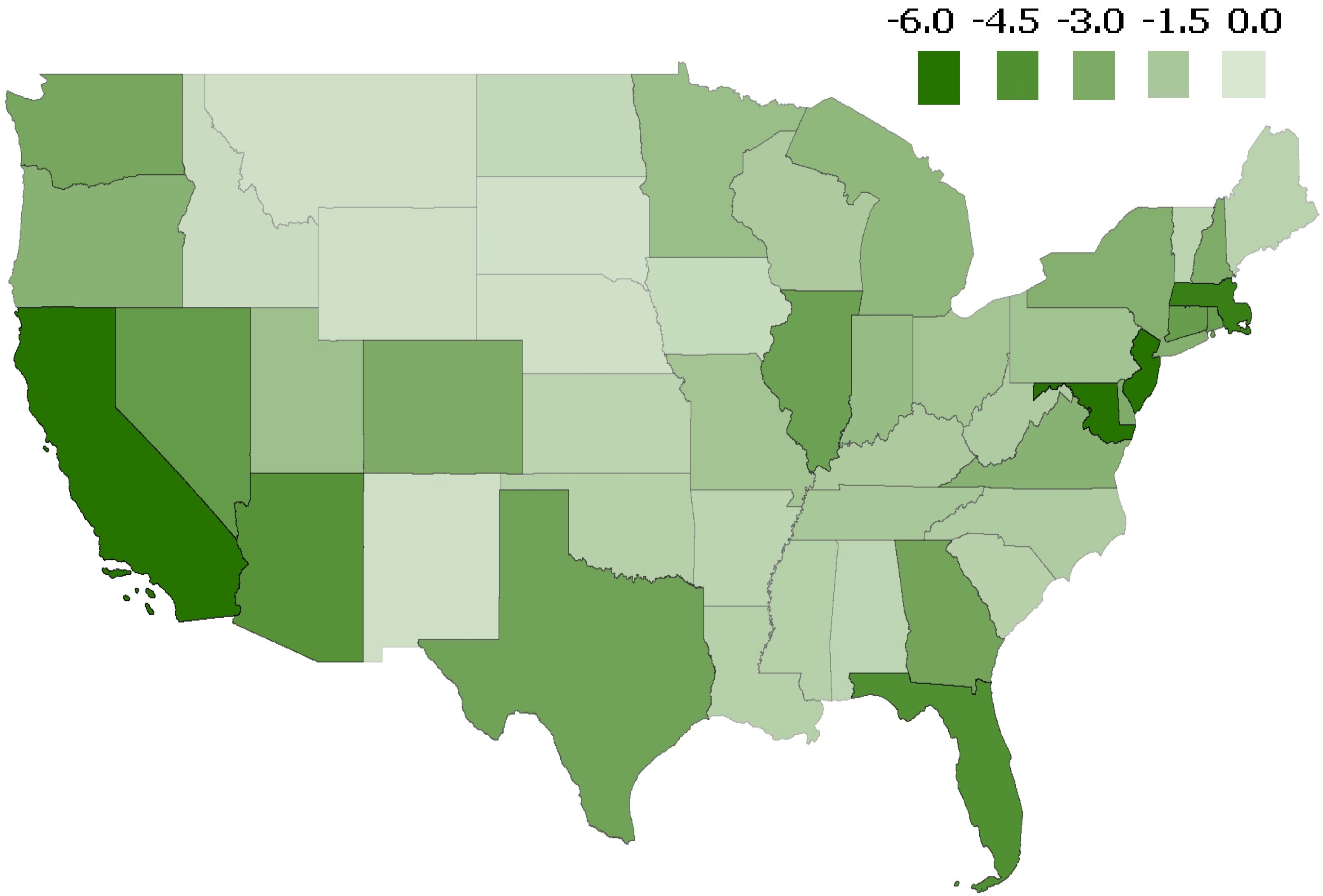
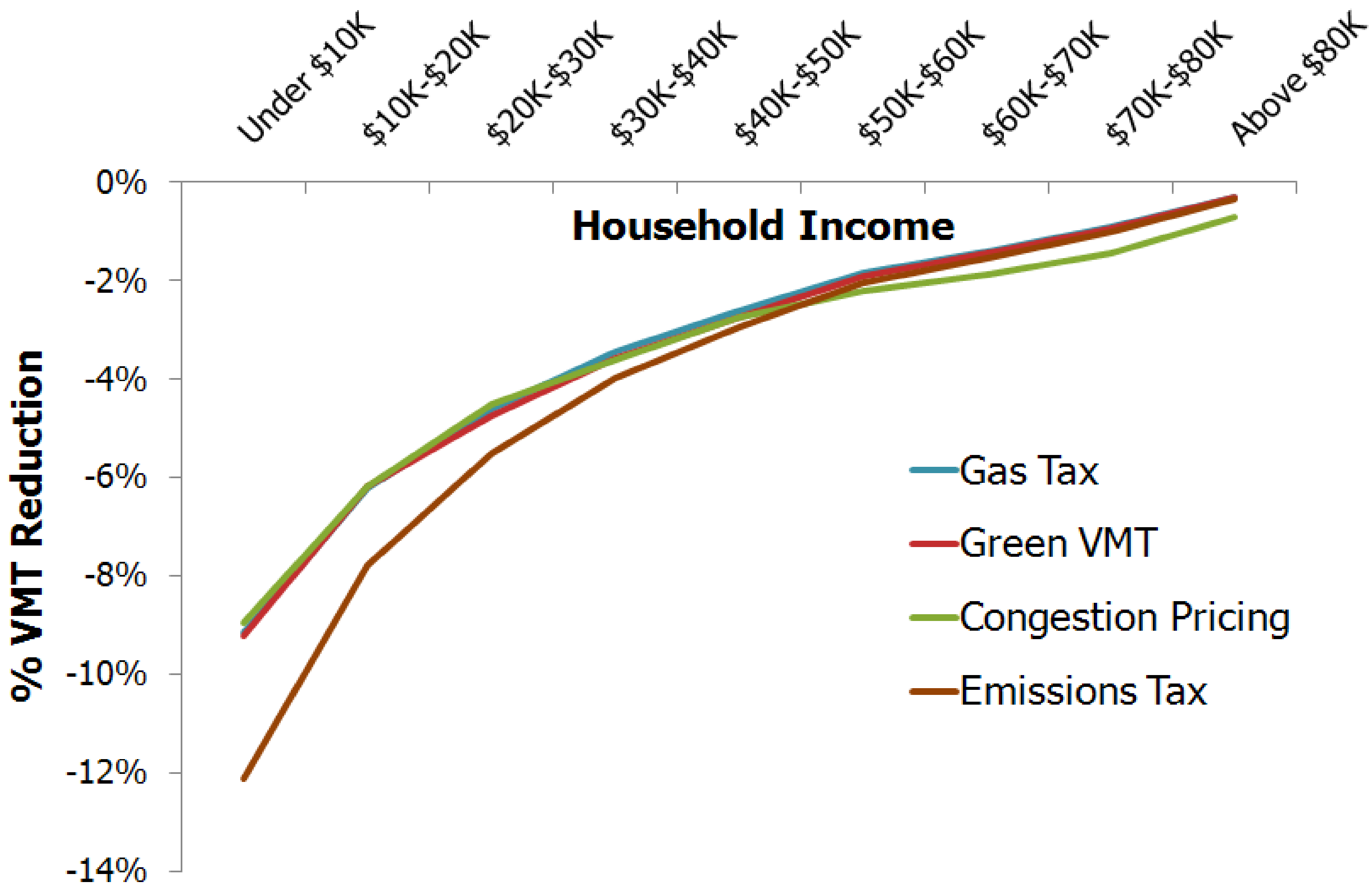
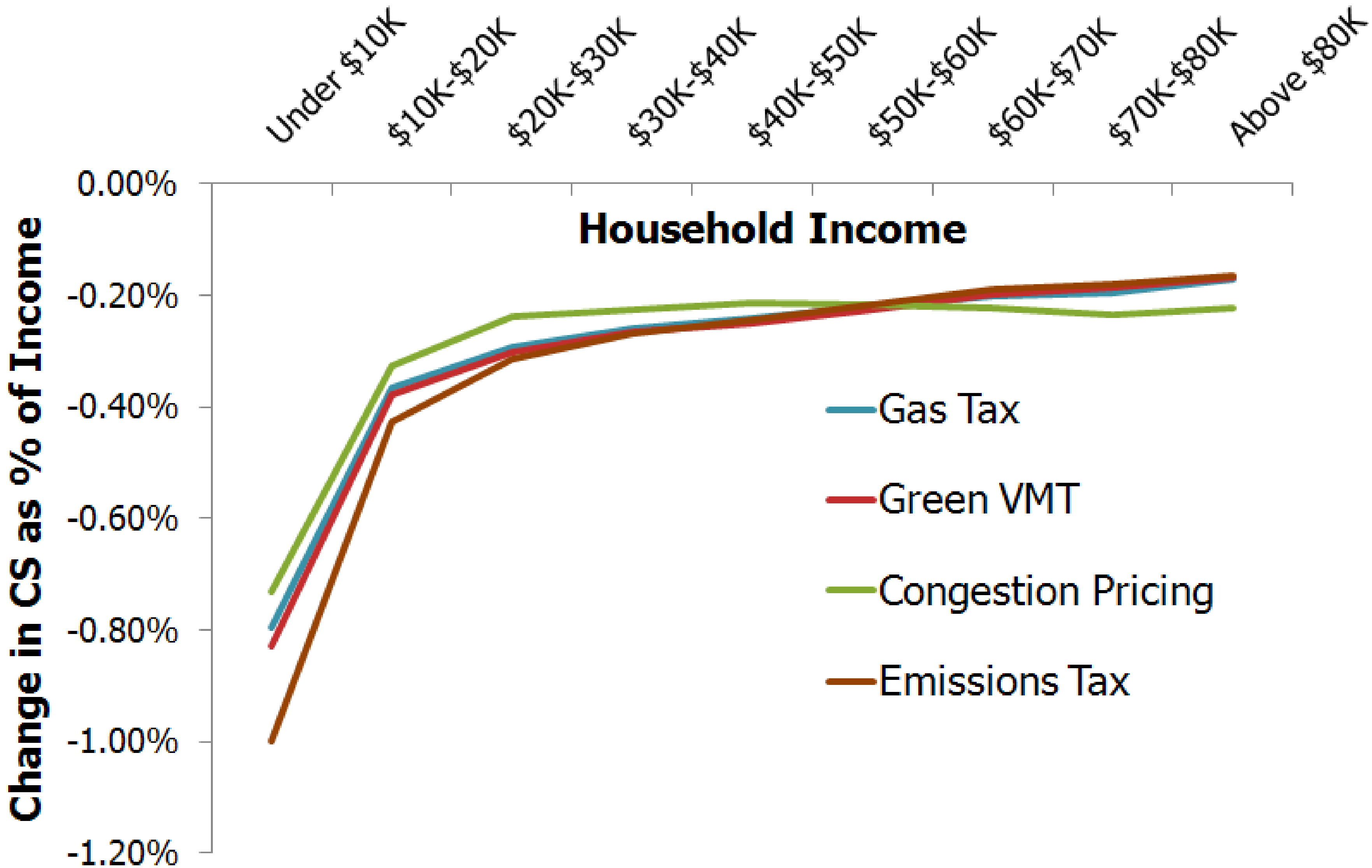


Figure 3. Percent Change in VMT by State under Nation-Wide Congestion Pricing

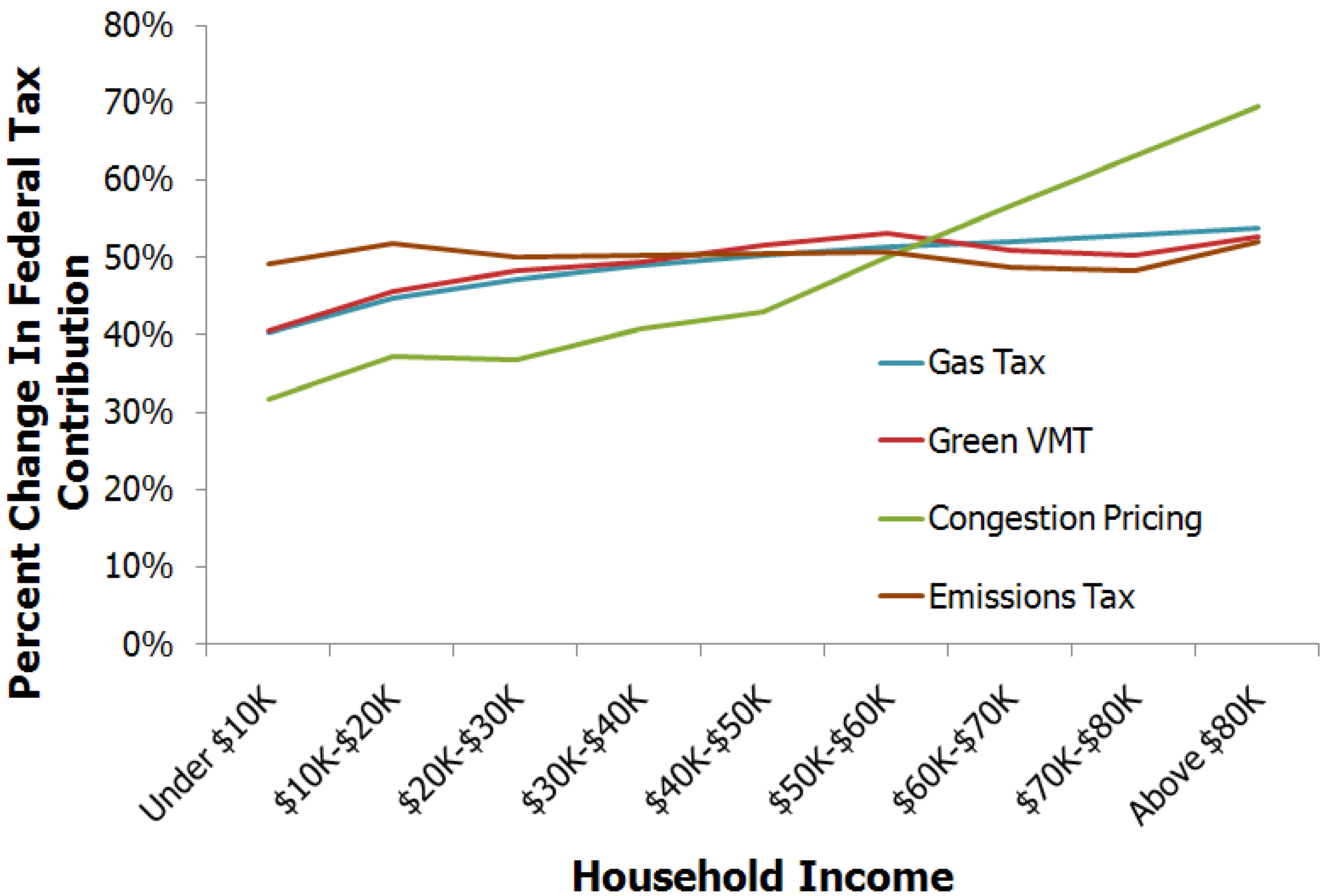
Figure 4. Distributional Effects of Green Financing Policies by Income Groups



a. Household Percent VMT Reduction

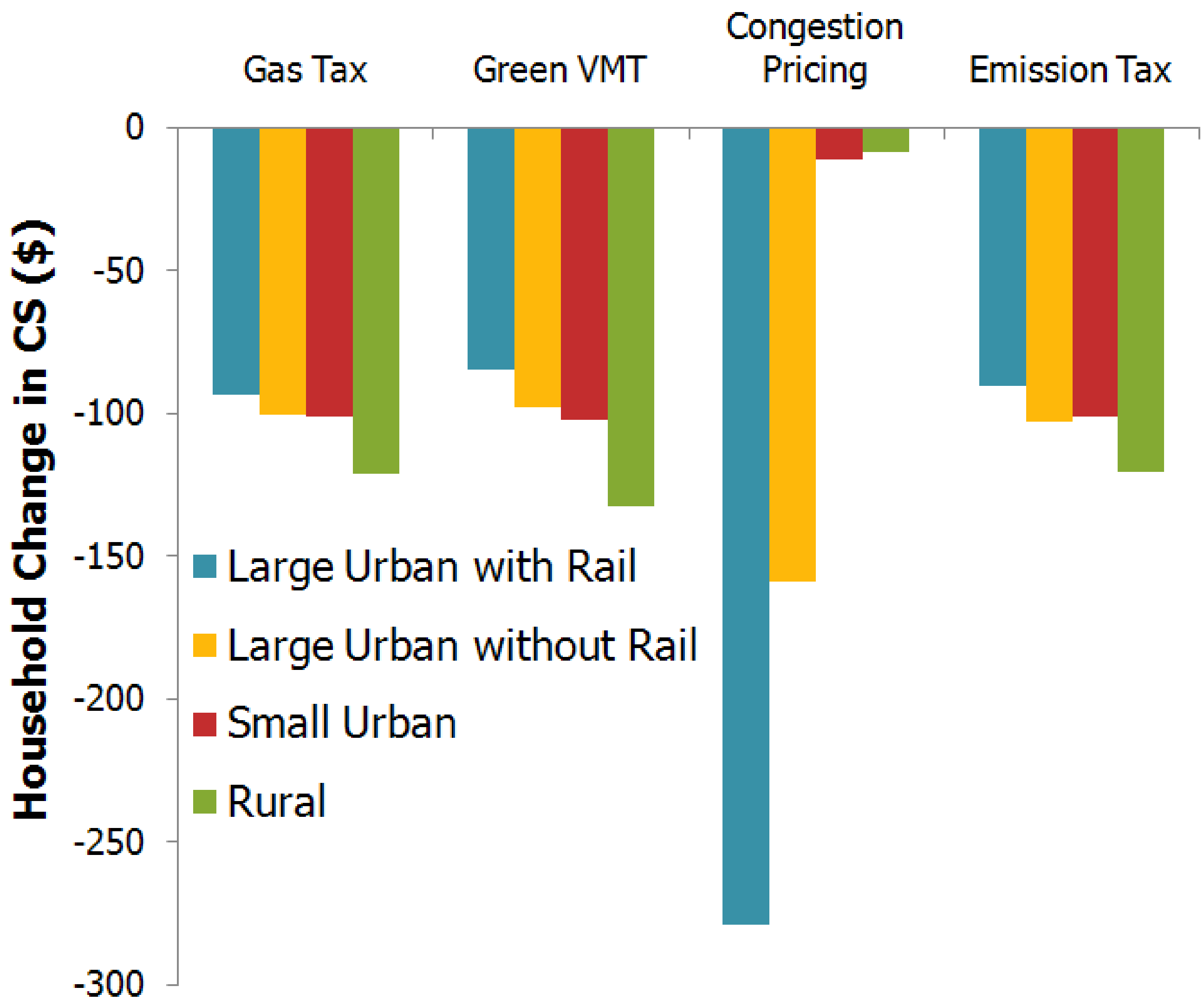


b. Household Change in Consumer Surplus as a Percentage of Income

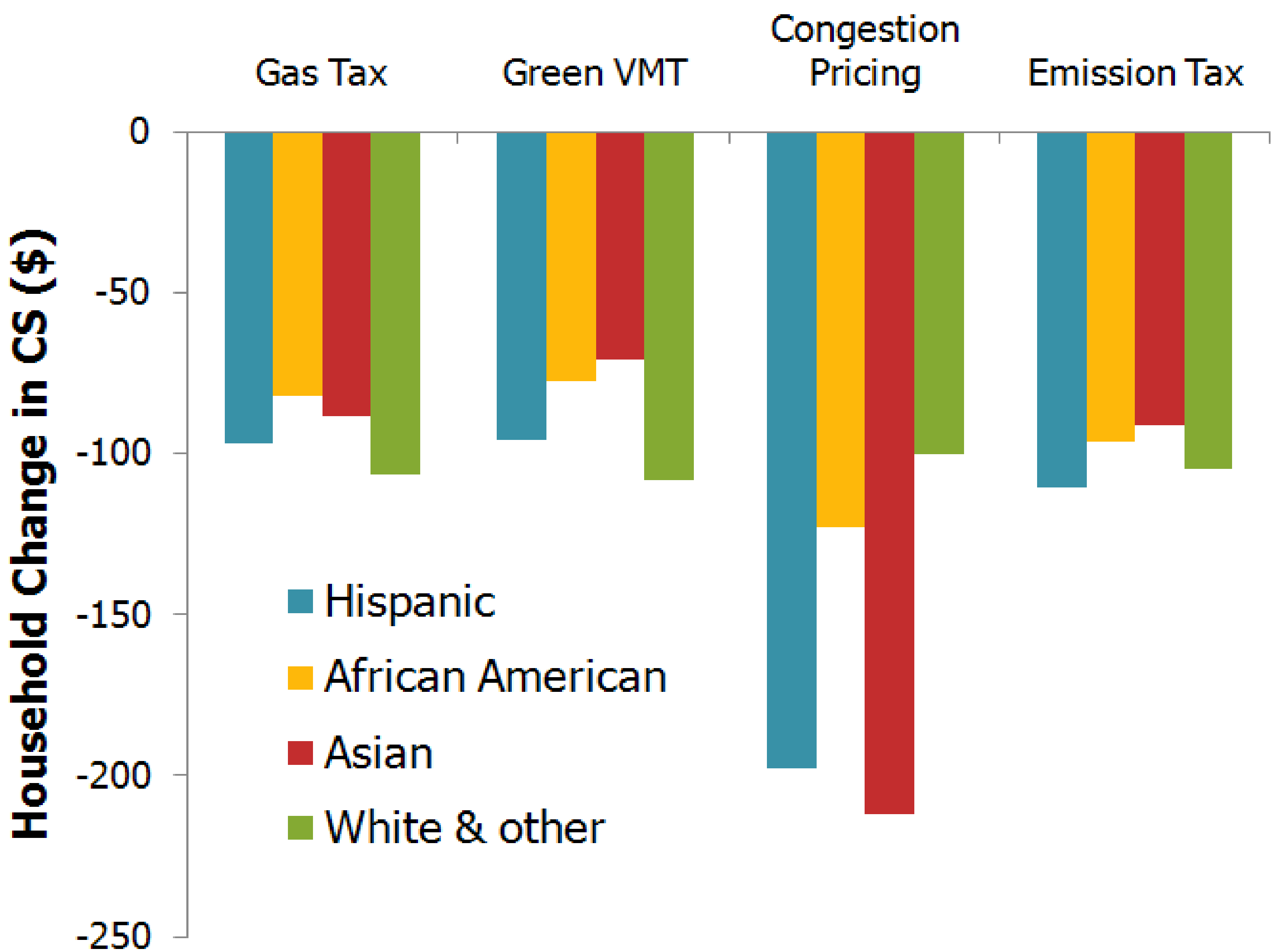


c. Household Percent Change in Federal Tax Contribution

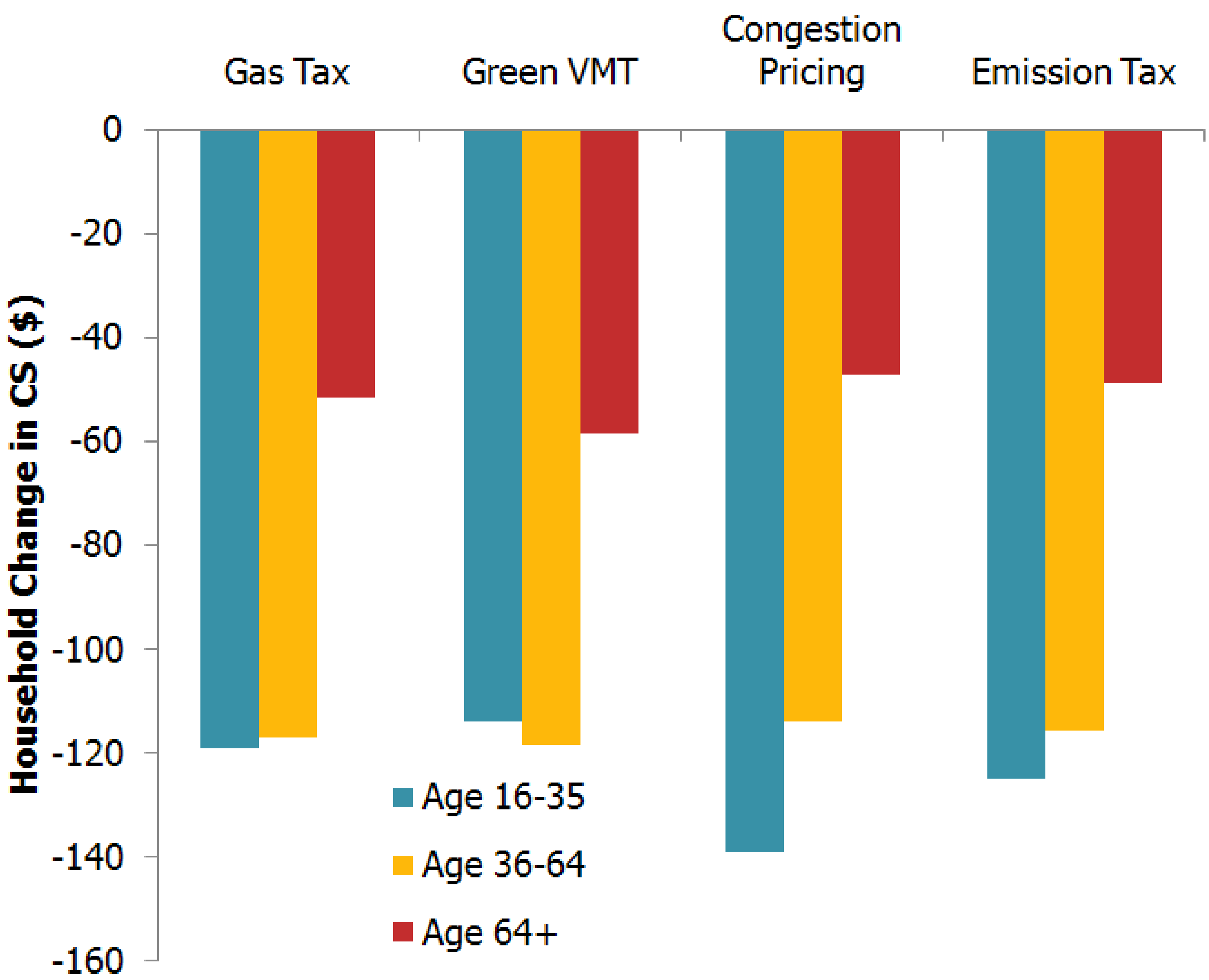
Figure 5. Household Change in Consumer Surplus ($) by Level of Urbanization, Ethnicity, and Age Group



a. Level of Urbanization



b. Ethnicity Group



Gas Tax
Green VMT
Congestion Pricing
Emission Tax
Household Change in CS ($)
0
-20
-40
-60
-80
-100
-120
-140
-160
Age 16-35
Age 36-64
Age 64+

c. Age Group

Table 1 Regression Coefficient Estimates and Variable Definitions

Variable	Coefficient Estimate	T-statistical significance	P>t	Explanation
Fuelcost/mile	-5.111	-26.36	0	cost of fuel per mile based on current vehicle ownership
Income	1.341	26.99	0	Household income
Income Fuelcost/mile*	0.420	22.86	0	Income multiplied by fuel cost/mile
Subsitute Fuelcost/mile*	0.421	14.85	0	Substitute multiplied by fuel cost per mile
Vehicle count	0.746	71.39	0	Number of vehicles owned by the household
Substitute	1.164	15.19	0	Household's ability to substitute driving between a less fuel efficient vehicle and a more fuel efficient vehicle
Male	0.089	13.16	0	If the call respondent at the household is a male
Worker count	0.085	15.73	0	The total number of workers residing at the household
Driver count	0.102	14.66	0	The total number of drivers residing at the household
Children count	0.039	11.5	0	The total number of children at the household
African American	-0.012	-0.87	0.384	If the call respondent is African American
Asian	-0.094	-3.56	0	If the call respondent is Asian
Hispanic	0.041	2.04	0.042	If the call respondent is Hispanic
Age 16-35	0.398	32.75	0	If the call respondent is between the ages of 16 and 35
Age 36-64	0.266	25.75	0	If the call respondent is between the ages of 36 and 64
Population density	-0.061	-26.25	0	Household census tract population density
MSA category 1	0.016	1.29	0.196	Households located in a Metropolitan Statistical Area with >1 million population and access to rail transit
MSA category 2	0.029	2.69	0.007	Households located in a Metropolitan Statistical Area with >1 million population but no access to rail transit
MSA category 3	-0.025	-2.55	0.011	Households located in a Metropolitan Statistical Area with a population less than one million people
Transit trips	-0.134	-7.23	0	The number of household public transit trips taken per day
Constant	-6.924	-13.23	0	Constant variable

Table 2. Household Changes in Welfare ($) and Percent Change in VMT from Green Financing Policies by Income

a. Green VMT Fee

Income Group	Average Change in CS	Change in state revenue attributed by each population subgroup	Change in Aggregate Welfare associated with each subgroup	Percent change in VMT
>/=$0,<$10K	$ (42.03)	$ 31.68	$ (10.35)	-9.23%
>/=$10K,<$20K	$ (57.62)	$ 48.24	$ (9.38)	-6.18%
>/=$20K,<$30K	$ (77.01)	$ 67.57	$ (9.44)	-4.76%
>/=$30K,<$40K	$ (94.23)	$ 85.46	$ (8.76)	-3.59%
>/=$40K,<$50K	$(113.87)	$ 105.87	$ (8.00)	-2.73%
>/=$50K,<$60K	$(125.68)	$ 119.58	$ (6.10)	-1.92%
>/=$60K,<$70K	$(129.89)	$ 124.99	$ (4.90)	-1.45%
>/=$70K,<$80K	$(140.73)	$ 137.31	$ (3.42)	-0.93%
>=$80K	$(150.84)	$ 149.83	$ (1.02)	-0.30%

b. Congestion Pricing

Income Group	Average Change in CS	Change in state revenue attributed by each population subgroup	Change in Aggregate Welfare associated with each subgroup	Percent Change in VMT
>/=$0,<$10K	$ (35.26)	$ 24.67	$ (10.60)	-8.94%
>/=$10K,<$20K	$ (49.44)	$ 39.35	$ (10.09)	-6.19%
>/=$20K,<$30K	$ (61.01)	$ 51.59	$ (9.42)	-4.52%
>/=$30K,<$40K	$ (80.09)	$ 70.48	$ (9.60)	-3.63%
>/=$40K,<$50K	$ (96.92)	$ 88.33	$ (8.58)	-2.75%
>/=$50K,<$60K	$(120.02)	$ 112.36	$ (7.66)	-2.22%
>/=$60K,<$70K	$(146.65)	$ 139.52	$ (7.13)	-1.88%
>/=$70K,<$80K	$(178.58)	$ 172.63	$ (5.94)	-1.43%
>=$80K	$(201.36)	$ 198.20	$ (3.16)	-0.71%

c. Emission Tax

Income Group	Average Change in CS	Change in state revenue attributed by each population subgroup	Change in Aggregate Welfare associated with each subgroup	Percent Change in VMT
>/=$0,<$10K	$ (50.63)	$ 38.39	$ (12.24)	-12.11%
>/=$10K,<$20K	$ (65.00)	$ 54.60	$ (10.41)	-7.78%
>/=$20K,<$30K	$ (79.59)	$ 70.14	$ (9.44)	-5.53%
>/=$30K,<$40K	$ (95.00)	$ 86.77	$ (8.23)	-3.97%
>/=$40K,<$50K	$(110.78)	$ 103.58	$ (7.20)	-2.93%
>/=$50K,<$60K	$(119.58)	$ 114.12	$ (5.46)	-2.06%
>/=$60K,<$70K	$(124.05)	$ 119.71	$ (4.33)	-1.54%
>/=$70K,<$80K	$(135.03)	$ 131.89	$ (3.14)	-1.02%
>=$80K	$(149.22)	$ 148.25	$ (0.97)	-0.34%

Table 3. Household Changes in Welfare ($) and Percent Changes in VMT from Green Financing Policies by Socio-Demographic Groups

a. Green VMT Fee

	Average Change in CS	Change in state revenue attributed by each population subgroup	Change in Aggregate Welfare associated with each subgroup	Percent Change in VMT
MSACAT1	$ (84.57)	$ 79.31	$ (5.26)	-2.29%
MSACAT2	$ (98.12)	$ 92.19	$ (5.94)	-2.32%
MSACAT3	$(102.36)	$ 95.33	$ (7.03)	-2.66%
Rural	$(132.48)	$ 123.12	$ (9.36)	-2.91%
Hispanic	$ (95.73)	$ 86.59	$ (9.14)	-3.58%
African American	$ (77.51)	$ 71.01	$ (6.51)	-3.01%
Asian	$ (70.68)	$ 65.95	$ (4.73)	-2.39%
Other	$(107.97)	$ 101.02	$ (6.95)	-2.51%
Age Group 16-35	$(113.79)	$ 105.83	$ (7.96)	-2.69%
Age Group 36-64	$(118.37)	$ 111.56	$ (6.81)	-2.23%
64+	$ (58.50)	$ 52.35	$ (6.15)	-4.34%

b. Congestion Pricing

	Average Change in CS	Change in state revenue attributed by each population subgroup	Change in Aggregate Welfare associated with each subgroup	Percent Change in VMT
MSACAT1	$(278.85)	$ 256.49	$ (22.36)	-7.12%
MSACAT2	$(159.08)	$ 148.03	$ (11.05)	-4.10%
MSACAT3	$ (11.29)	$ 10.31	$ (0.98)	-0.69%
Rural	$ (8.55)	$ 7.75	$ (0.80)	-0.53%
Hispanic	$(198.02)	$ 174.80	$ (23.22)	-6.94%
African American	$(123.16)	$ 111.47	$ (11.68)	-4.73%
Asian	$(211.67)	$ 193.63	$ (18.04)	-6.26%
Other	$(100.20)	$ 93.05	$ (7.15)	-2.45%
Age Group 16-35	$(138.88)	$ 126.67	$ (12.21)	-3.58%
Age Group 36-64	$(113.85)	$ 106.51	$ (7.34)	-2.26%
64+	$ (46.98)	$ 41.74	$ (5.24)	-3.56%

c. Emission Tax

	Average Change in CS	Change in state revenue attributed by each population subgroup	Change in Aggregate Welfare associated with each subgroup	Percent Change in VMT
MSACAT1	$ (90.64)	$84.89	$ (5.75)	-2.85%
MSACAT2	$(103.18)	$96.98	$ (6.21)	-2.79%
MSACAT3	$(101.30)	$94.50	$ (6.80)	-3.02%
Rural	$(120.22)	$111.96	$ (8.26)	-3.05%
Hispanic	$(110.49)	$100.06	$(10.44)	-4.61%
African American	$ (96.48)	$88.33	$ (8.15)	-4.17%
Asian	$ (91.36)	$84.55	$ (6.81)	-3.55%
Other	$(105.06)	$98.48	$ (6.57)	-2.80%
Age Group 16-35	$(125.00)	$115.72	$ (9.28)	-3.51%
Age Group 36-64	$(115.75)	$109.31	$ (6.44)	-2.48%
64+	$ (49.00)	$44.21	$ (4.79)	-4.10%

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