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DISSERTATION

Mileage-Based User Fee Winners and Losers

An Analysis of the Distributional Implications of Taxing Vehicle Miles Traveled, With Projections, 2010–2030

Brian A. Weatherford

This document was submitted as a dissertation in March 2012 in partial fulfillment of the requirements of the doctoral degree in public policy analysis at the Pardee RAND Graduate School. The faculty committee that supervised and approved the dissertation consisted of Martin Wachs (Chair), Howard Shatz, and Thomas Light.

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ABSTRACT

The mileage-based user fee (MBUF) is a leading alternative to the gasoline tax. Instead of taxing gasoline consumption, the MBUF would directly tax drivers based on their vehicle miles traveled (VMT). Equity is a commonly raised public acceptance concern regarding MBUFs. This study uses household-level survey data of travel behavior and vehicle ownership from the 2001 and the 2009 National Household Travel Survey (NHTS) to estimate changes in annual household demand for VMT in response to changes in the cost of driving that result from adopting MBUF alternatives. Distributional implications are estimated for an equivalent flat-rate MBUF, an increased fuel tax rate and it's equivalent flat-rate MBUF, and three alternative MBUF rate structures: a 1 cent MBUF added to the current fuel tax, a tiered rate MBUF based on vehicle fuel economy, and a much increased MBUF rate. The distributional implications are then projected over the years 2015 - 2030 under eight different macroeconomic and policy scenarios.

The research finds that a flat-rate MBUF would be no more or less regressive than fuel taxes, now or in the future. An increase in the tax rate, whether an MBUF or a fuel tax, causes transportation revenue collection to become less regressive because low income households have a more elastic response to changes in price than middle and high income households. MBUF "winners" include retired households and households located in rural areas. On average, an MBUF would reduce the tax burdens of these groups. MBUF "losers" are households in urban and suburban areas. The projections suggest that the distributional implications of MBUFs are unlikely to change in future years. Changes in the cost of driving, either from a higher tax rate, or other factors, appears to have a greater impact on the equity of transportation finance than whether the tax is collected by the gallon or by the mile. These results are robust to alternative sources of data and model assumptions.

The findings are significant because they suggest that equity considerations based on ability to pay will not be a significant reason to oppose or support the adoption of MBUFs. While the equity implications of MBUFs are minimal, however, some groups, especially rural states, may find that the potential equity benefits of MBUFs could be overwhelmed by an increase in the tax rate to cover the higher costs of collecting and administering them. Concerns about the impacts of flat-rate MBUFs on vehicle fuel efficiency and greenhouse gas emissions are valid but, at current oil prices, the tax rate is a small percentage of the total cost of gasoline. Therefore, the overall price signals still encourage fuel efficiency. Regardless, it is possible to structure an MBUF that provides incentives for fuel efficiency while maintaining other favorable qualities of MBUFs such as their economic efficiency and fiscal sustainability.

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CONTENTS

GLOSSARY

Symbol	Definition
AAA	American Automobile Association
AEO	*Annual Energy Outlook*
BLS	Bureau of Labor Statistics
CAFE	Corporate Average Fuel Economy
CBO	Congressional Budget Office
CPI	consumer price index
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EV	electric vehicle
FHWA	Federal Highway Administration
GAO	Government Accountability Office
GHG	greenhouse gas
GPM	gallons per mile, $GPM = MPG^{-1}$
HEV	hybrid-electric vehicle
HTF	Highway Trust Fund
MBUF	mileage-based user fee
MPG	miles per gallon, $GPM = MPG^{-1}$
NHTS	National Household Travel Survey
NHTSA	National Highway Traffic Safety Administration
OECD	Organization for Economic Co-operation and Development
ORNL	Oak Ridge National Laboratory
PHEV	plug-in hybrid electric vehicle
PRGS	Pardee RAND Graduate School
RV	recreational vehicle (motor home)
SAFETEA–LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SUV	sport utility vehicle
TRB	Transportation Research Board of the National Academies
VMT	vehicle-miles traveled

1. MILEAGE-BASED USER FEES

MOTOR FUEL TAXES ARE NOT A VIABLE LONG-TERM SOURCE OF TRANSPORTATION REVENUE

Roads in the United States are generally provided by the public sector and funded using public revenue. Gasoline and diesel fuel taxes provide a third of all public revenues that are used to operate, maintain and expand the surface transportation system in the United States.[1] A diversity of general fund sources and user fees comprise the remaining amount. As the largest single source of highway revenue, there is considerable public interest in understanding the efficiency, equity, and the long-term viability of fuel taxes (Committee for the Study of the Long-Term Viability of Fuel Taxes for Transportation Finance 2006; Congressional Budget Office 2011).

The motor fuel tax is constantly under pressure from two sources: increasing construction costs and increasing vehicle fuel efficiency. Throughout the history of the fuel tax, legislators have had difficulty routinely increasing the gasoline and diesel fuel tax rates so that total fuel tax revenue keeps pace with funding needs.[2] The costs of constructing and maintaining roads have grown rapidly, more rapidly, by some accounts, than the overall consumer price index (CPI) and certainly faster than the federal gasoline tax rate (Luo 2011). The federal gasoline tax was last increased in 1993 and, since then, the CPI has advanced by 51 percent and the California Construction Cost Index has advanced by 82 percent.[3]

At the same time, total fuel tax receipts fail to keep pace with the amount of travel. As vehicle fuel economy improves, the amount of tax collected for each mile traveled declines. As total vehicle miles traveled (VMT) increases, there is an increased need for highway maintenance and to expand the capacity of existing roads and transit systems. Vehicle fuel efficiency, which is typically measured in miles per gallon (MPG), dramatically improved during the 1980s following an increase in fuel prices and the adoption of the Corporate Average Fuel Economy (CAFE) standards in 1975 (National Highway Transportation Safety Administration 2011). Further improvements to vehicle fuel economy slowed during the late 1990's and yearly 2000's as the initial CAFE standards were completely phased in and gasoline prices reached historic lows.[4] Vehicle fuel efficiency is, however, once again improving rapidly. Gasoline prices increased by 134 percent, from $1.75 per gallon in July 2002 to just over $4.00 in July 2008, and consumers are responding by purchasing more fuel efficient cars. Sales of highly fuel efficient hybrid electric vehicles (HEV), in particular, are growing faster than the overall automobile market (CBSNews July 6, 2009).

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[1] This includes transit and excludes private infrastructure. In 2008, federal, state, and local fuel taxes generated approximately $78 billion in revenue; total highway and transit revenue across all levels of government was $235 billion (FHWA, 2010; Federal Transit Administration, 2010). For comparison, private railroads generated $61.2 billion in operating revenue in 2008 (Association of American Railroads, 2010).

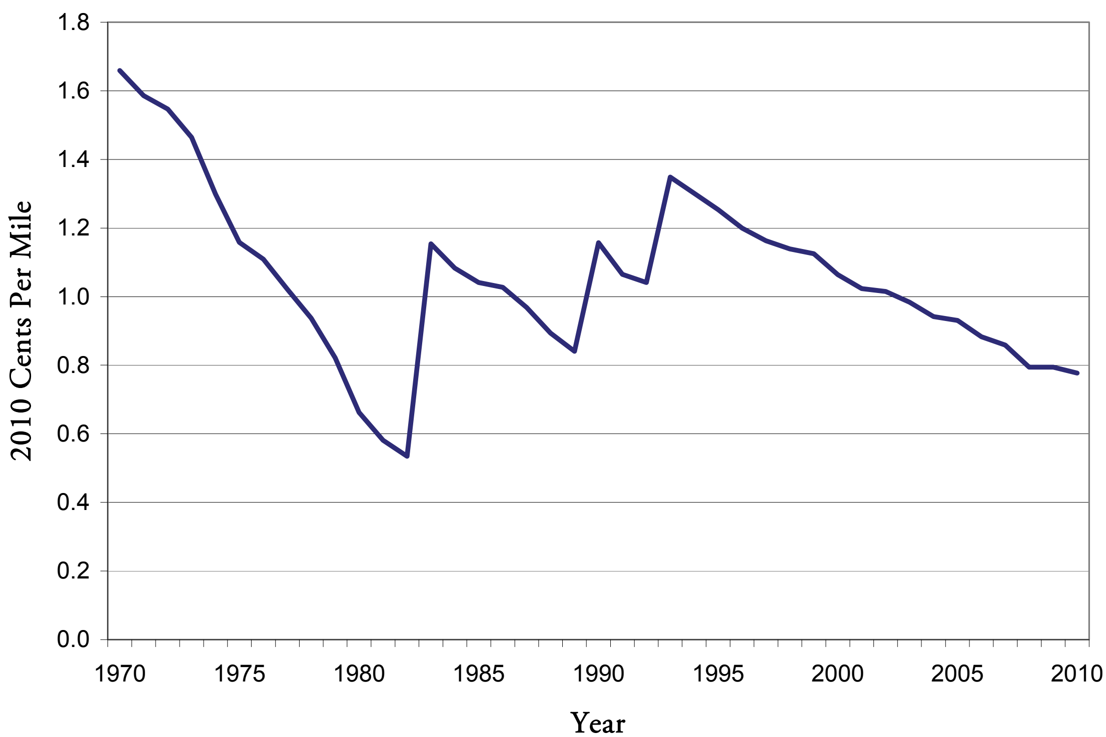
[2] The federal gasoline tax rate is 18.4 cents per gallon of gasoline and 24.4 cents per gallon of diesel. All states levy a per-gallon excise tax and many also impose an ad valorem sales tax. In addition, many states allow local governments to levy a local option excise or sales tax on gasoline. In January 2011, total taxes on gasoline ranged from 20.4 cents per gallon in Alaska to 66.1 cents per gallon in California; the volume-weighted national average was 48.1 cents per gallon of gasoline and 53.1 cents per gallon of diesel (American Petroleum Institute, 2011).

[3] Highway construction costs are more volatile than the CPI and are subject to competition from construction in other sectors and from global competition for steel, cement, and other commodities. For example, construction costs tracked by the California Department of Transportation fell sharply between 2006 and 2010. This index, where 2007 = 100, was 42.2 in 1993, 104.1 in 2006, 95 in 2008, 78.4 in 2009 and 76.8 in 2010. The percent change 1993-2010 is 82 percent.

[4] Gasoline prices reached a historic low in February 1999 with an average nominal price (all formulations, including taxes) of $0.96 per gallon equivalent to $1.27 in real 2010 dollars (US Energy Information Administration 2011).

The result is that the real value of the fuel tax is steadily declining. While some states, such as Maine and Wisconsin, regularly adjust their fuel tax rates, federal fuel tax rates were last increased in 1993 (Ang-Olson, Wachs, and Taylor 2000; Federal Highway Administration 2010). Since then, as illustrated in Figure 1.1, the real value of the federal gasoline tax has declined by 42 percent. Without an immediate increase in the fuel tax rate, an unlikely event, this trend will accelerate over the coming years. Several sets of increasingly stringent CAFE regulations, currently applying to new light duty vehicles through model year 2016 and heavy duty vehicles though model year 2018, have been adopted by the Environmental Protection Agency (EPA) and the National Highway Transportation Safety Administration (NHTSA) since 2006 (US NHTSA 2011). The Energy Information Administration (EIA) projects that, given current policy and technology, the fuel efficiency of the overall vehicle population will improve by 25 percent between 2010 and 2030 (US EIA 2011a). This will cause the average fuel tax rate (per mile) to fall proportionately, prior to accounting for deleterious effects of inflation. Additional mandates to improve vehicle fuel efficiency, along with further technical advances to enable those reductions, are obviously possible, if not highly likely.

Figure 1.1: Federal Gasoline Tax Rate, Real Cents per Mile Traveled, 1970 - 2010



Note: The real tax rate is calculated using the CPI. Alternatively, it is possible to use a construction cost index, such as the previously described California Construction Cost Index, which might more accurately reflect the real value of the tax rate with respect to constructing transportation projects. However, the volatility of construction commodity prices could mask the underlying historical trends of increasing prices overall and increasing average vehicle fuel economy. Therefore, all dollar values in the dissertation, unless otherwise noted, are in 2010 dollars, after adjusting for inflation using the CPI (all urban consumers, all items, not seasonally adjusted, series id# CUUR0000SA0).
Sources: Federal Highway Administration (FHWA), *Highways Statistics Series*, 1995-2009, Tables FE-101A, VM-201A and VM-1.

Additionally, fully electric vehicles (EV) and plug-in hybrid-electric vehicles (PHEV) are now being sold to consumers by major automobile manufacturers. While there are currently a small number of electric vehicles on the road, the market for this technology is poised to grow rapidly and could account for 5-15 percent of the automobile market by 2020 (Bedi et al. 2011). Estimates for sales volumes of EV and PHEV automobiles vary and are highly speculative but nonetheless stimulate further concern about the long-term viability of gasoline taxes because these vehicles pay little to no tax (Ang-Olson, Wachs, and Taylor 2000; Dignan 2010; Eisenstein 2010; Hajiamiri 2010). The real value of the fuel tax, relative to funding needs, will continue to decline as construction costs rise, vehicle fuel economy continues to improve and the number of EVs sold increases. It is unclear whether federal gasoline and diesel taxes will be able to generate sufficient revenue to maintain and improve the nation's surface transportation network in future years.

Three separate commissions were formed between 2003 and 2009 to review national transportation finance needs and sources of revenue. The earliest, the Committee for the Study of the Long-Term Viability of Fuel Taxes for Transportation Finance, was convened by the Transportation Research Board of the National Academies (TRB).[5] This committee met between 2003 and 2005 to consider the challenges and the benefits of the gasoline tax against the likely opportunities and obstacles of alternative sources of revenue (Committee for the Study of the Long-Term Viability of Fuel Taxes for Transportation Finance 2006). The committee concluded that fuel taxes would be viable over the next two decades but reform was necessary. Specifically, this committee recommended that fuel taxes should be maintained and increased in the short-term. The public sector should also begin to transition towards charging highway users directly based on the number of miles traveled, instead of on fuel consumption. The committee expressed support for expanded use of toll roads and toll lanes on free highways to better manage congestion and to generate some additional revenue. However, the committee endorsed taxes on miles traveled as "the most promising technique for directly assessing road users for the costs of individual trips within a comprehensive fee scheme that will generate revenue to cover the costs of the highway program" (Committee for the Study of the Long-Term Viability of Fuel Taxes for Transportation Finance 2006, 4).

The 2005 federal transportation authorization bill, the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA–LU), created two separate commissions with similar mandates; both would assess current revenues and possible alternatives and make recommendations to Congress. Section 1909 of SAFETEA–LU established the National Surface Transportation Policy and Revenue Study Commission (2007). The "Policy Commission" consisted of 12 members. They presented their findings, which were not unanimous, to Congress in 2007. The Commission's Chairwoman, Secretary of Transportation Mary Peters, was among three dissenting commissioners who argued that the primary problem facing the nation's transportation system was not insufficient revenue but an inability to manage demand. Both the dissenting group and the majority of the Policy Commission agreed that the use of tolling and congestion pricing be

[5] The candidate's dissertation committee chair, Professor Martin Wachs, was one of the 14 members of this committee.

expanded and that a vehicle mileage-based user fee (MBUF) should be considered. In particular, the dissenting group writes:

> "Thanks to technology development and the leadership of a number of State and local officials, the move toward direct pricing is underway at the State and local level. A change from an indirect to a direct pricing system can and should ensure continued access to transportation systems for all Americans, regardless of income. In fact, when contrasted to the highly regressive nature of higher fuel taxes and congestion itself, direct pricing is likely to be a far more fair system" (National Surface Transportation Policy and Revenue Study Commission 2007, 67).[6]

The majority of the Policy Commission recommended that the next transportation authorization bill fund "a major national study to develop the specific mechanisms and strategies for transitioning to an [MBUF] alternative to the fuel tax to fund surface transportation programs" (National Surface Transportation Policy and Revenue Study Commission 2007, 53).

Section 11142 of SAFETEA–LU established the 15 member National Surface Transportation Infrastructure Financing Commission (2009). The "Financing Commission" reported their unanimous findings to Congress, the Department of Transportation, and the Department of the Treasury in 2009. While the work of this commission overlaps considerably with the work of the Policy Commission, the focus of their study is "on how revenues should be raised, including whether there are other mechanisms or funds that could augment the current means for funding and financing highway and transit infrastructure" (National Surface Transportation Infrastructure Financing Commission 2009, 5). The Financing Commission's findings echo the findings and recommendations of the two prior study groups; the current system of indirectly taxing travel by taxing users' fuel consumption is unsustainable over the long-term and the system must transition to direct charges on VMT (National Surface Transportation Infrastructure Financing Commission 2009, 7-16).

It is remarkable that these three disparate groups agree on the need to replace the gasoline tax with an MBUF despite conflicting conclusions regarding when the fuel tax will no longer be viable, how much funding is ultimately needed, the role of the federal government in transportation relative to the states, the types of transportation projects that should be funded by the federal government, and how these investments should be prioritized. This reflects or, perhaps, is motivating a growing consensus among senior transportation policy experts and advisors that transportation will be primarily funded by direct user charges instead of gasoline taxes (Forkenbrock and Hanley 2006; Shane et al. 2010). While there is consensus regarding the general concept and the need for a vehicle mileage-based tax or user fee, there remains considerable disagreement about the technical details, timeline, costs, benefits, system impacts, and social effects of MBUFs.[7]

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[6] The term "regressive" means that the tax burden falls more heavily on low income taxpayers than on high income taxpayers relative to their ability to pay. It is the opposite of a "progressive" tax such as the federal income tax.

[7] A tax on VMT is commonly referred to as a "Mileage-Based User Fee" or a "VMT fee." The use of the term "fee" may be a conscious, intentional semantic choice by those advocating for the adoption of one. Following conventional usage, the term "MBUF" will be used though out the dissertation but it is always treated as a tax. The distinction between a user fee and a tax is important although there remains some disagreement over the intent and the precise legal definition of a "user fee." In general, the revenue from a tax can be used for any purpose while the revenue from a user fee may only be used to provide the public good or service on which the fee is being charged (Gillette and Hopkins 1987). There are often further distinctions between the ease to levy and change the rate of a tax (difficult) and a user fee (relatively easy).

MOVING TOWARDS A TAX ON VEHICLE MILES TRAVELED

The concept of an MBUF is an appealing alternative to the gasoline tax because it could be more economically efficient, fiscally sustainable, accurate and transparent (Parry and Small 2005; Forkenbrock and Hanley 2006; Safirova, Houde, and Harrington 2007; Sorensen, Wachs, and Ecola 2010; Baker and Goodin 2011). These potential benefits have led to several technical feasibility studies and trials (Forkenbrock and Kuhl 2002; Donath et al. 2003; Whitty 2007; Puget Sound Regional Council 2008; Sorensen et al. 2009; Sorensen, Wachs, and Ecola 2010; Baker and Goodin 2011; Public Policy Center 2011; US CBO 2011). While many see the MBUF as a future alternative, there is interest in taking immediate steps to begin transitioning away from the gasoline tax to the MBUF (Forkenbrock 2005; Sorensen et al. 2009). Given the level of interest in the MBUF concept, there is a growing body of research on various aspects of MBUFs spanning technical feasibility concerns (Donath et al. 2003) to consumer perceptions (Baker and Goodin 2011). Two large-scale MBUF technical feasibility trials have been completed; one in Oregon (Whitty 2007) and the other in the Puget Sound metropolitan region of Washington (Puget Sound Regional Council 2008). A major national trial is being conducted by the University of Iowa in 12 locations around the country (Sorensen, Wachs, and Ecola 2010; Public Policy Center 2011). These trials have demonstrated the proof of concept and have stimulated interest in funding additional trials in other states and a more extensive national trial (National Surface Transportation Policy and Revenue Study Commission 2007; Sorensen, Wachs, and Ecola 2010).

The primary motivation for considering the adoption of an MBUF is better revenue sustainability. Improving vehicle fuel efficiency and the growth in the consumer market for EVs and PHEVs will continue to diminish the value of the fuel taxes (Hajiamiri 2010). While the MBUF will not be immune from inflationary pressure, it will staunch the deleterious effects on revenue from these forces. Further, if successfully implemented as a user fee, the MBUF may be politically easier to adjust for changes in construction costs. An MBUF is not the only response to the falling real value of the fuel tax. The fuel tax is supplemented in many states with local fuel taxes, state and local sales taxes, and general funds. Shortfalls in the HTF have been supplemented with more than $30 billion in general funds since 2008 (US General Accountability Office 2010). However, an MBUF may be preferred by some because it has economic efficiency advantages over these alternatives.

MBUFs can be more economically efficient than gasoline taxes and general fund sources for several reasons. A flat-rate MBUF more directly reflects many of the costs of driving, including externalities such congestion, accidents and some air pollutants. With the exception of carbon dioxide emissions and their impact on the risk of global warming, these externalities are more directly related to VMT than to fuel consumption (Parry, Walls, and Harrington 2007).[8] A direct tax on VMT is also more efficient than fuel taxes because of the rebound effect.[9] There is no direct relationship between driving and sales or income, although there is certainly an indirect correlation, making these the least economically efficient tax mechanism.

There are various methods of metering and reporting a vehicle's VMT for the purpose of charging drivers an MBUF with varying degrees of accuracy, geographic resolution, technical sophistication, cost, and burden on the user (Sorensen et al. 2009). A more technologically advanced method could vary the mileage charge by road being travelled and by the time of day (Sorensen, Wachs, and Ecola 2010). This has many potential benefits. Among these benefits is the potential to

[8] Local air pollutants, such as carbon monoxide, nitrogen oxides, and suspended particulates are regulated by the mile.

[9] The rebound effect describes how consumers respond to fuel taxes and higher gasoline prices not only reducing VMT but also by purchasing more fuel efficient vehicles. The more efficient vehicles reduce the per-mile cost of driving and so consumers respond by increasing VMT, partially offsetting the reduction expected from the per-gallon price increase.

adopt a rate structure that varies by the road being traveled and by the time of day. Variable pricing could be used to reduce traffic congestion very effectively and is the greatest source of potential benefit to highway users (Parry, Walls, and Harrington 2007). By managing travel demand more efficiently and effectively, investment needs could also be minimized (Small and Van Dender 2007). Adopting a sophisticated MBUF collection system would also allow for an improved understand of where transportation investments are most urgently needed.

An MBUF collection system that allows for accurately charging users based on exactly where on the transportation system they have driven also allows for a more accurate spatial understanding of travel demands. This will enable a more accurate apportionment of revenue to local jurisdictions and prevent interstate tax evasion.[10] Currently, it is possible to know with certainty only where the fuel was purchased and not where it is consumed. This more accurate data may also be used to better calibrate transportation planning models which may lead to improved long-term plans (Sorensen, Wachs, and Ecola 2010). The potentially high level of detail and accuracy of the data raises concern for traveler privacy.

There are several concerns about MBUFs which may offset the potential benefits. One of the first concerns expressed by members of the general public upon hearing about MBUF proposals is privacy (Baker and Goodin 2011). The technical feasibility studies have demonstrated that user privacy can be protected (Forkenbrock and Kuhl 2002; Whitty 2007; Sorensen, Wachs, and Ecola 2010). Nonetheless, the perception among the public that MBUF metering systems can be used by the government to track individuals will likely persist.

Another significant problem with MBUFs is the higher cost of administering, collecting and enforcing the tax. Fuel taxes are collected indirectly from users at central distribution points and the total costs are about 1 percent of total revenue (Balducci et al. 2011). With no MBUF system in operation anywhere in the world, it is not possible to accurately estimate the costs of a state or national system at this time. The costs of accurately collecting the fee directly from every driver, enforcing compliance, and managing disputes will undoubtedly be higher than the fuel tax. The closest analogue to an MBUF, in operation, is a toll road. These require an average of 34 percent of revenue to operate and collect (Balducci et al. 2011). A full scale MBUF system will likely be more efficient than a single tolled road, but the costs will clearly be greater than under the current fuel tax. Adopting an MBUF to support current levels of public funding of transportation will necessarily require a higher tax rate in order to generate sufficient revenue to offset the increase in collection, administration, and enforcement costs. Analysts have proposed that benefits from additional services could help to partially offset the higher costs (Sorensen, Wachs, and Ecola 2010; Baker and Goodin 2011).

Some of these other potential benefits to drivers from an advanced MBUF collection system include "pay as you drive" (PAYD) automobile insurance, automated parking and toll payment, location dependent travel and safety services, and media connectivity services for vehicle passengers (Sorensen, Wachs, and Ecola 2010). While these possible benefits are promising, more research is needed to understand whether they are actually feasible and how much drivers will value them. More research is also needed to understand the equity implications of MBUFs, another frequently expressed concern and potential benefit (Cambridge Systematics 2009; Taylor 2010; Baker and Goodin 2011).

[10] Interstate tax evasion is when residents of a state with a high fuel tax rate travel to another state to purchase motor fuel taxed at a relatively lower rate. Alternative MBUF implementations will, however, introduce new and varied possibilities for tax evasion.

THE EQUITY IMPLICATIONS OF MBUFS ARE UNCERTAIN

Charging drivers by the mile instead of by the gallon is a major policy change with uncertain implications for the distribution of the tax burden among households. The overall equity of MBUFs will likely be similar to that of fuel taxes because of the close relationship between total VMT and total fuel consumption (Parry and Small 2005). Nonetheless, the distributional implications are uncertain because the distribution of vehicle fuel economy across income levels and other groups of households within the population may change over time. The distribution of vehicle fuel economy determines, in part, the relative equity implications when moving from a fuel tax to an MBUF. This distribution appears to be changing as fuel prices rise, vehicle fuel economy regulations become increasingly stringent, and a variety of alternative fuel vehicles become commercially available. In addition, there are other characteristics of households and groups of households that can influence changes in distribution of the burden of a tax which are even more difficult to directly observe and predict. With MBUF implementation far from certain and far from immediate, the uncertainty only increases with time.

Several prior studies, all using the 2001 National Household Travel Survey, find that replacing the fuel tax with a flat rate MBUF would reduce the taxes paid by low income and rural households and increase the taxes paid by middle income and urban households (Zhang et al. 2009; McMullen, Zhang, and Nakahara 2010; Weatherford 2011). These findings are consistent with other research on the equity of the gasoline tax that shows that low income and rural households own vehicles that are older and less fuel efficient than the overall population (West 2005; Bento et al. 2009). Households owning less fuel efficient vehicles would benefit from a flat-rate MBUF because their current fuel tax rate per mile is higher than households that own high-MPG vehicles (Baker, Russ, and Goodin 2011). These prior studies of the distributional implications of MBUFs all use data from a survey, the 2001 NHTS, conducted more than a decade ago. They only consider the equity implications from one type of flat-rate MBUF that generates the same, or approximately, the same amount of revenue, and do not estimate how future macroeconomic conditions or future improvements in vehicle fuel economy might affect the equity of an MBUF. Research is needed to more fully, comprehensively, and confidently understand the equity implications of MBUFs.

This dissertation presents the methodological approach and the results of a comprehensive policy research study of the equity implications of MBUFs. Specifically this dissertation answers the question:

- What are the distributional implications of adopting an MBUF to replace or supplement the gasoline tax as a future source of public revenue for maintaining and expanding the surface transportation system?

And, to this end, it answers the following three research questions:

- Are MBUFs more or less regressive than fuel taxes?
- Who are the winners and losers of a flat-rate MBUF?
- How do alternative MBUF rates and rate structures affect the distributional implications of MBUFs relative to fuel taxes and each other?

The results are projected over the future years 2015-2035 and under alternative future macroeconomic conditions in order to understand how sensitive the results are to assumptions about future changes in prices, household income, and vehicle fuel economy.

Chapter 2 introduces specific equity concepts and reviews the findings from equity studies of gasoline taxes and other travel related fees and charges such as toll lanes and emissions taxes. Chapter 3 describes the data used in this study, the 2001 and 2009 NHTS. Chapter 4 describes the methodological approach followed in this study. Chapter 5 presents and discusses the results of the distributional implications of MBUF policy alternatives. Chapter 6 presents and discusses the results of the projections of the distributional implications of MBUFs in years 2015-2035. Chapter 7 concludes the dissertation with a discussion of the limitations of the research, opportunities for further research, and guidelines for considering equity in MBUF policy.

2. THE EQUITY OF HIGHWAY USER FEES AND TAXES

Equity is a critical concern in the analysis and comparison of tax policies (Brewer and deLeon 1983; Musgrave and Musgrave 1989; Taylor 2010). Policy makers and taxpayers are often interested in whether a new tax will be more or less "equitable." However, equity concepts can be imprecisely defined and susceptible to a subjective evaluation (Levinson 2010). This dissertation investigates the relative distributional implications of implementing MBUF taxes of various designs. In other words, relative to the existing tax system, who will pay more tax, or less, relative to others after adopting an MBUF? Who will benefit more, or less, relative to others from any change in tax revenue and externalities?

The incidence of a tax describes how much of a tax is paid by producers and how much is paid by consumers (Musgrave and Musgrave 1989). For most goods, regardless of whether the tax is directly levied on a supplier, as is the case with fuel taxes, or a consumer, the tax burden is shared.[11] Tax burden is a phase that describes the price and income effect of a tax dollar all are impacted by the taxis split between the two. The proportion of the tax burden paid by each party varies depending on the structure of the market, the price elasticity of demand relative to the price elasticity of supply, and other factors (Musgrave and Musgrave 1989). While the direct incidence of the current gasoline tax falls on the gasoline distributor, the consumer pays all or nearly all of an increase in the tax rate (Alm, Sennoga, and Skidmore 2009).

The most obvious difference between a fuel tax and an MBUF is the change in the party upon which the tax is initially levied. Otherwise, as long as vehicle choice is held constant, the societal incidence of the tax is not expected to differ from the gasoline tax since both directly affect consumers driving behavior regarding whether or not to take a trip.[12] Instead of a higher-level consideration of incidence, this dissertation is focused on understanding how the burden of similar taxes varies between households and groups of households. In addition to the amount of tax paid as a part of their costs of driving, households also bear the burden of a fuel tax or MBUF in other ways. Were there no tax, for example, the cost of driving would be lower and so households would make a marginal number of additional trips (McCarthy 2001). Driving also results in various externalities such as traffic congestion and air pollution (Parry and Small 2005; West 2005). In addition, the revenue raised by the tax does not leave the economy. As previosuly discussed in Chapter 1, fuel tax and MBUF revenues are used to finance the maintenance and expansion of the transportation system with socail benefits. The fiscal and social benefits of a tax can partially ofset the economic costs imposed on society and the distribution of these benefits should be considered when comparing tax burdens of various groups (Bento et al. 2009; Levinson 2010).

EXTERNALITIES AND PIGOUVIAN TAXES

Many taxed goods have negative externalities associated with their use or consumption. Cigarettes, for example, produce a health risk to the individual, but also create costs for society, including secondhand smoke and insurance and healthcare costs that are not internalized by the individual. A Pigouvian tax adds the marginal social cost of consumption to a good with

[11] A number of terms are defined in this Chapter but no effort has been made to do so rigorously and mathematically. It would be tedious to read and duplicative of much good work that has preceded this dissertation. Many excellent references are cited for those readers seeking further clarity.

[12] As discussed later in Chapter 3, once the vehicle choice assumption is relaxed other incidence changes are possible. This effect is relatively small (Bento et al. 2009).

externalities in order to cause the consumer to internalize the full cost of consuming the good, and reduce their demand to the socially optimal level (Baumol and Oates 1988).

Gasoline taxes are sometimes promoted as a Pigouvian tax to reduce fuel consumption and the risk of global climate change (Mankiw 2008). In addition, economists have long examined ways to price travel more efficiently to manage demand to reduce urban traffic congestion and reduce infrastructure investment needs (Mohring and Harwitz 1962). MBUFs, as discussed in the previous chapter, are promoted on efficiency grounds because they may help to reduce the demand for VMT to more socially optimal levels.

Despite the welfare effects of certain taxes, welfare is not typically considered in distributional analyses of taxes although in some cases there are important welfare implications of the tax which should be considered (Parry, Walls, and Harrington 2007). This study is the first to examine the full distributional implications of net changes in household welfare from adopting MBUFs. In fact, very few studies of the distributional implications of transportation finance consider the change in the distribution of the externalities of driving despite the large marginal social costs of travel and fuel consumption (Parry, Walls, and Harrington 2007).

PRIOR FINDINGS REGARDING THE EQUITY OF FUEL TAXES AND ROAD PRICING

Generally, estimates of the distribution of the gasoline tax burden, especially using cross-sectional data, find it to be highly regressive (West 2002). There are several qualifications regarding the relative regressivity of motor fuel taxes. Calculating lifetime fuel expenditures over lifetime income suggest that the fuel tax is "far less regressive" than studies of annual expenditure suggest (Poterba 1991). However, a later study concludes that gasoline taxes are regressive for most people because only a small proportion of individuals are only temporarily poor (Chernick and Reschivsky 1997). Nonetheless, the finding that fuel consumption, and therefore fuel tax burden, varies over an individual's lifetime is pertinent to this dissertation. One set of groups examined in the distributional analysis are life cycle groups. Different types of households have quite different travel needs and their tax burdens vary as a result, as do the distributional implications of adopting an MBUF.

Some studies find that low income households have a higher price elasticity than do high income households.[13] Studies that do not allow the price elasticity to vary with income may also overstate the regressivity of the gasoline tax (West and Williams III 2004). Low income households are more responsive to changes in the price of gasoline than high income households. A reduction in fuel consumption comes at the cost of travel and mobility and this has further equity implications. Other research finds that equity implications of raising the fuel tax can vary with differences in car ownership and travel behavior across income groups and that, when controlling for income, there were also "significant differences in impacts across racial categories and regions of residence" (Bento et al. 2009).

There is less experience with various forms of road pricing than with the motor fuel excise tax and, therefore, there are also fewer empirical studies of the equity of pricing (Levinson 2010). Such projects do raise significant equity concerns among the public and there are, consequently, a great many studies which have found that the distributional implications of adopting a cordon toll, tolling a road, or just several lanes of a road depend on the socio-economic characteristics of the people who use the road (Ecola and Light 2009; Levinson 2010). These characteristics can vary considerably from one place to the next and it is possible for any single road pricing project to be

[13] This is discussed in Chapter 3.

"regressive, progressive, or neutral" depending on the socioeconomics of the travelers before and after pricing is implemented (Santos and Rojey 2004).

MBUFs are expected to be less regressive than fuel taxes because low income households own vehicles with lower average fuel efficiency and also own a higher proportion of light trucks, which are typically less fuel efficient than many automobiles, than do households with higher income (West 2005; Bento et al. 2009; Baker, Russ, and Goodin 2011). Also, while high income households make longer trips than do low income households, the difference is less than 1 mile and this also "suggests that any user tax proportional to [VMT] would be regressive" (Pucher and Renne 2003). Prior research on the equity of MBUFs has not arrived at a strong consensus regarding whether they would be more or less regressive than the full tax (Valluri 2008; Zhang et al. 2009; McMullen, Zhang, and Nakahara 2010; Weatherford 2011). These studies consistently find that the tax burdens of rural households are reduced while the tax burdens of urban households are increased.

GEOGRAPHICAL AND JURISDICTIONAL EQUITY OF TRANSPORTATION FINANCE

In addition to understanding the equity implications of adopting an MBUF on individuals and groups, one of the most important aspects of equity with respect to policy analysis is how it might impact the distribution of federal-aid transportation funding to the states (Wachs 2003; Kirk 2004; Taylor 2010; US GAO 2010). States are identified as "donor" and "donee" states based on the proportion of total federal transportation funding each state receives relative to the proportion of total user fee revenue contributed. It is possible that MBUFs will have two characteristics that could impact the jurisdictional equity of transportation finance. The first is that states with large rural populations will likely contribute less revenue and states with large urban populations will contribute more revenue because of a difference in the average fuel efficiency of urban and rural households. The distributional implications of this are unknown, but are examined in this research. In addition, MBUFs will improve the transparency of exactly where travel occurs and end inter-state "leakage" in which drivers purchase gas in a state with a low fuel tax for consumption in a state with a relatively high fuel tax. This problem also exists within states, not only due to differentials in tax rates, but also the availability and location of fueling stations. Better transparency could result in allocating revenues more equally between and within the states, but, as with the effects of changing the share of contributions between rural and urban states, the ultimate effects cannot be known.

CONTRIBUTION OF RESEARCH TO POLICY AND TO KNOWLEDGE

Decision makers may need to understand who the winners and losers of a policy are for two reasons. The first is to understand which groups can be expected to support or oppose the policy and why. This allows for decision makers and advocates assemble political coalitions that support their position with respect to the policy. The second reason to identify the winners and losers is to provide a foundation upon which to negotiate the details of the MBUF policy and the tradeoffs that will need to be made within the specific details of the policy, or perhaps other policy initiatives, in order to move the concept of an MBUF from being a proposal through the legislative process and to eventually incorporate an MBUF in a transportation funding authorization and appropriations legislation. Understanding the incentives of political decision makers and for the political process may ultimately shape an MBUF is also important to understanding and interpreting the equity implications of MBUFs (Holcombe 1998).

This dissertation also makes several unique contributions to knowledge. The research updates MBUF equity studies using more recent data and several methodological improvements. In particular, this study improves the methodology of the only prior national-level study of the distributional implications of MBUFs by strongly improving the estimated price elasticities of demand for VMT as described in Chapter 3 (Weatherford 2011). This study is also the first to directly compare the differences in the estimated collection and administration costs between fuel taxes and MBUFs or any other alternative to fuel taxes, a contribution made possible by recent research to estimate those costs by Balducci et al. (2011). Lastly, while most sophisticated distributional analyses of fuel taxes and their alternatives consider the distribution of changes in household welfare, these typically include only the change in consumer surplus and net revenue. This study is one of the first, if not the first, to add the net change in the externalities of driving and fuel consumption to the net change in revenue (Parry, Walls, and Harrington 2007).

3. DATA AND MODEL

This chapter describes the 2001 and the 2009 National Household Travel Surveys (NHTS) which are the primary sources of data used in this study. After describing the data, the functional form of the linear regression model used to estimate changes in household demand for VMT in response to change in the cost of driving due to changes in tax policy is developed and explained. This model is fit using the NHTS data and the predictor variables are then described and discussed.

DATA

The NHTS is a nationally representative survey of US households. It provides detailed information on daily travel for each household member, household composition, income, geographic location, and vehicle ownership (US FHWA 2004a, 2011).[14] The data include variables for vehicle fuel economy and fuel prices estimated by the EIA and variables for vehicle annual VMT estimated by Oak Ridge National Laboratory (ORNL). The most recent survey, the 2009 NHTS, was conducted between 2008 and 2009. The version of the 2009 NHTS used in this analysis, Version 2.1, was released in February 2011 (US FHWA 2011).

The 2009 NHTS data are pooled with data from a prior survey, the 2001 NHTS, that was conducted between 2001 and 2002 (US FHWA 2004b). Some data cleaning is necessary to ensure consistency between the variables and those procedures are detailed in the Technical Appendix. The naming convention used by FHWA to refer to the two surveys is confusing. The earlier survey is named the "2001 NHTS" for the year in which it commenced while the most recent survey is named the "2009 NHTS" for the year in which it concluded. The proper survey name is referred to when directly describing the data. However, inferences based on the survey data are more accurately referred to as "2001-02" and "2008-09."

The 2001 NHTS includes 26,038 households and the 2009 NHTS includes 150,147 households.[15] These surveys do not have, and are not intended to have, sufficient power to draw statistically significant inferences for some states (US FHWA 2004b, 2011). Twenty state and local governments purchased "add-on" samples for planning and modeling purposes in the 2009 NHTS. States that are oversampled are Arizona, California, Florida, Georgia, Indiana, Iowa, New York, North Carolina, South Carolina, South Dakota, Tennessee, Texas, Vermont, Virginia, and Wisconsin.[16]

Summary statistics for the 2001 and 2009 NHTS are provided in Table 3.1. There are two columns for each survey; the first contains sample means and standard deviations calculated from the sample excluding households that do not own a vehicle. The second column contains statistics calculated from the entire sample. Five percent of the observations in the 2009 NHTS, corresponding to 8.6 percent of households in the population after adjusting for sampling errors, do not own a vehicle. Households that do not own vehicles have zero VMT and therefore lower the average VMT of the sample. These households also have missing information on relevant vehicle characteristics such as the cost of driving and fuel economy.

[14] The publically available NHTS was used instead of the "confidential" NHTS.

[15] The total sample size of the 2001 NHTS is 69,817 including nine state and local government "add-ons". It is not possible to consider the "full" sample, however, because estimates for vehicle fuel economy and VMT were not added to the add-on observations. The "national" sample includes correct sampling weights and is most consistent with the 2009 NHTS, despite the large differences in sample size.

[16] New York, Texas, and Wisconsin also purchased add-on samples in the 2001 NHTS.

A change in transportation tax policy will not directly impact households that do not own any vehicles. However, their welfare is affected by changes in externalities such as air pollution, for example, that affect all households equally regardless of how much they drive. The average income of households that do not own a vehicle is 66 percent lower than other households. Given this large difference in income, it is necessary to account for all households to avoid overestimating the regressivity of fuel taxes and MBUFs.

Table 3.1 shows that VMT per household has declined by eight percent between 2001-02 and 2008-09. The two factors that are most likely driving this trend are higher fuel prices and the economic recession that began in 2008. Retail gasoline prices rose by 88 percent, from $1.64 to $3.08, in constant 2010 dollars. Meanwhile, the economic recession increased unemployment and reduced average incomes (Hurd and Rohwedder 2010). The summary statistics in Table 3.1 appear to reflect these effects of the economic recession with the average number of workers per household falling by 17 percent and income in households earning less than $100,000 per year falling by 4 percent.[17] These statistics may also reflect the demographic trends of shrinking and aging households.[18] Nonetheless, both employment and income are positively correlated with VMT.

Table 3.1 highlights other relevant trends in vehicle and household characteristics. The average "on-road" fuel economy of household vehicles increased by 2 percent.[19] In addition, the average age of household vehicles increased by about 7 months. Household size declined slightly, with 4 percent fewer people and 2 percent fewer drivers.

The average annual fuel tax also declined in real dollars between the 2001 NHTS and the 2009 NHTS. This is due in part to lower VMT. However, these figures also reflect a decline in the real tax rate, on a per-mile basis, as discussed in previous chapters. The 18.4 cent per gallon federal gasoline tax rate generated 1.1 cents per mile in 2001-02. By 2008-09 this had fallen to 0.9 cents per mile with inflation and the small improvement in average vehicle fuel economy. The average per-household state fuel tax fell by less than the average per-household federal fuel tax because some states increased their fuel tax rates during this period.

As previously noted, on-road vehicle fuel economy has improved by 2 percent, from 20.7 MPG to 21.1 MPG. While the fuel economy of new vehicles, for both automobiles and trucks, improved over this period, consumers also began to purchase larger numbers of SUVs. This trend constrained the overall improvement in fuel efficiency because light trucks, a category that includes pickups and SUVs, are less fuel efficient than automobiles. The proportion of the population owning at least one light truck increased from 43 percent in 2001-02 to 50 percent in 2008-09.

Some readers may find the fuel economy statistics in Table 3.1 to be lower than expected. This is because the official EPA fuel economy ratings have been adjusted by the EIA to better reflect vehicle fuel efficiency under "real world" driving conditions (US EIA 2011b). The EPA measures vehicle fuel economy in a controlled setting and these have been criticized as being unrealistic (Sallee 2010, 35). In order to better estimate actual household motor fuel consumption, the EIA uses a model to adjust, typically lower, the EPA fuel economy based on certain household

[17] Income for the entire population actually rises by 4 percent, as shown in Table 3.1, because the average income of households earning more than $100,000 per year also rises.

[18] VMT, income, and fuel price are important variables that have been estimated, instead of directly observed. The methods used to estimate these variables are discussed later in this chapter. No attempt to causally link the economic and demographic trends cited here with these descriptive statistics has been made; it is sufficient to note that a number of factors have led to the observed reduction in household VMT between the two surveys.

[19] The official EPA vehicle fuel economy ratings that are familiar to most readers are adjusted in the NHTS by the EIA to better reflect actual driving conditions which typically reduce the fuel efficiency of vehicles. The method used by the EIA to estimate these "on-road" fuel economy statistics is described in the text later in this chapter

Table 3.1 Weighted Sample Means of Key Variables in 2001 NHTS and 2009 NHTS

	2001 NHTS		2009 NHTS	
	Households with vehicles	**All households**	**Households with vehicles**	**All households**
	Mean (St. Dev.)	Mean (St. Dev.)	Mean (St. Dev.)	Mean (St. Dev.)
Annual VMT (miles)	25,016 (22,198)	23,044 (22,346)	23,101 (19,101)	21,121 (19,375)
Retail fuel cost (dollars per gallon)	1.64 (0.13)	-	3.08 (0.14)	-
Household fuel economy (mpg)	20.71 (4.29)	-	21.10 (4.81)	-
Annual income (dollars)	69,605 (56,503)	65,987 (56,343)	72,567 (62,490)	68,462 (62,138)
Federal fuel tax (dollars per year)	280.17 (291.90)	258.08 (290.15)	210.42 (192.81)	192.38 (193.54)
State fuel tax (dollars per year)	287.38 (287.60)	264.73 (286.69)	237.82 (229.78)	217.44 (229.57)
Household size (number of people)	2.65 (1.43)	2.59 (1.44)	2.54 (1.40)	2.48 (1.42)
Number of workers	1.42 (0.98)	1.36 (0.99)	1.19 (0.86)	1.13 (0.87)
Number of drivers	1.89 (0.80)	1.78 (0.88)	1.85 (0.78)	1.75 (0.85)
Number of vehicles	2.06 (1.08)	1.89 (1.17)	2.04 (1.10)	1.87 (1.19)
Vehicle age	7.81 (4.25)	-	8.36 (4.41)	-
Sample observations	24,615	26,038	143,084	150,147
Usable observations	19,659	20,856	125,936	131,900

Note: Dollar values are in 2010 dollars, after adjusting for inflation using the CPI.

characteristics such as annual VMT and geographic location (US EIA 2011b). For comparison, the mean household EPA fuel economy in the 2001 NHTS is 25.1 MPG and 25.2 MPG in the 2009 NHTS. The estimated average annual tax using the EIA estimated fuel efficiency is approximately 20 percent higher that it would be were the EPA ratings used, but this difference varies by household complicating generalization.[20] These adjusted, on-road vehicle fuel economy estimates are used throughout the remainder of the dissertation unless explicitly stated otherwise.

There are incomplete data on household income, vehicle fuel economy, and annual VMT for 18,247 households (12 percent) in the 2009 NHTS and 5,182 households (20 percent) in the 2001 NHTS. These households cannot be used in the analysis and are dropped from the sample. In households with more vehicles, there is a greater likelihood that at least one vehicle is missing an estimate for its fuel economy or VMT and, therefore, these households are more likely to be dropped than households with few or no vehicles. To compensate for this bias, the sampling weights for the remaining households are normalized using a methodology described in the Technical Appendix that accounts for the number of vehicles per household.

[20] A sensitivity analysis is conducted using the EPA-estimated MPG, instead of the adjusted EIA estimates, and the results are discussed in Chapter 5. More detail about the EIA adjustment methodology may be found in Technical Appendix.

MODEL

Functional Form

The unit of analysis is the household. Each household owns an observed number of vehicles for which there is an estimated annual VMT and an estimated on-road fuel economy. These are aggregated to calculate each household's annual VMT and a VMT-weighted household average fuel economy (MPG). Household MPG is a continuous variable that determines each household's price per mile given its estimated fuel prices and taxes.

The dependent variable in the model is the natural log of annual VMT and the primary predictor is the natural log of the price per mile.[21] The relationship between VMT and its price and other covariates is initially estimated by adopting the basic linear specification in Equation 3.1:

$$\ln M_i = \alpha + \beta_1 \ln p_i + \beta_2 \ln Y_i + \beta_3 \ln V_i + \beta_4 \ln Dist_i + \beta_5 \ln Density_i + \beta_6 W_i \qquad (3.1)$$
$$+ \beta_{MULTI} + \beta_{TRANSIT} + \beta_{HH\_TYPE} + \beta_{LIFECYCLE} + \beta_{STATE} + \varepsilon_i$$

where:

$\ln M_i$	is the natural log of the annual miles traveled by household i,
$\ln p_i$	is the natural log of household i's price per mile,
$\ln Y_i$	is the natural log of household i's annual income,
$\ln V_i$	is the natural log of the number of vehicles available for use in household i,
$\ln Dist_i$	is the natural log of household i's furthest great circle distance to work,[22]
$\ln Density_i$	is the natural log of household i's population density (per square mile)
W_i	is the number of workers in household i,
$\beta_1 - \beta_6$	are parameters to be estimated using weighted least squares regression,
β_{MULTI}	is a parameter that is estimated if household i owns more than one type of vehicle (car, van, SUV, pickup, other truck, RV, motorcycle, other),
$\beta_{TRANSIT}$	is a parameter that is estimated if at least one member of household i has reported using transit at least once in the past month,
β_{HH_TYPE}	are 8 parameters that are estimated for 9 household type categories based on the ratio of adults to vehicles,
$\beta_{LIFECYCLE}$	are 2 parameters that are estimated for 3 household life cycle categories (household with children, comprised entirely of retired adults, and other),
β_{STATE}	are 51 parameters that are estimated for 52 states (includes Washington D.C. and another category for households with suppressed state codes),
α	is the estimated intercept term, and
ε_i	is the residual, the difference between the predicted natural log of annual VMT and the observed natural log of annual VMT, for household i.

Additional information about these variables is provided in the following section of this chapter. Technical details regarding how the variables were constructed are provided in the Technical Appendix. The coefficients and the residuals are estimated using weighted least squares regression using observations with one or more vehicles from the 2001 and 2009 NHTS.

The first two columns of Table 3.2 report the fitted coefficient values and their robust standard errors for each of the surveys separately. The third column reports the fitted coefficient

[21] The price per mile is a composite variable that includes the retail cost of gasoline, including all taxes, divided by household i's weighted MPG. In a later stage of this analysis, a per-mile tax is added to this variable along with changes in, or the elimination of, the gasoline tax rate in order to calculate the new household price per mile for the alternatives.

[22] The "great circle" distance is the shortest distance between two points on the surface of a sphere.

values and their robust standard errors for the pooled data.[23] All of the coefficients are statistically different from zero at a 1 percent significance level with each set of data. Both the 8 household type (*HH_TYPE*) and 51 state fixed effects (*STATE*) coefficients are jointly statistically significant at the 1 percent level.

The functional form of this model is a convenient approximation of household demand for VMT which is, in actuality, derived from the household's demand to travel to workplaces, marketplaces, and other destinations (Oum et al. 1995). The purpose of this model is to predict the change in each household's demand for VMT, given changes in the price per mile of travel calculated for each alternative tax policy.

The change in a household's demand for VMT with respect to the change in price is measured by the price elasticity of demand for travel.[24] The price elasticity is calculated by taking the partial derivative of the demand function specified in Equation 3.1 with respect to price. The log-linear functional form of Equation 3.1 is convenient because the coefficient of the natural log of price, β_1, can be interpreted as the price elasticity. The absolute value of the price elasticity estimated using either the 2001 NHTS or the 2009 NHTS individually is greater than 1.[25] This suggests that the demand for VMT is "elastic" with respect to price. Elastic price elasticity means that consumers are "sensitive" to changes in price and will reduce their demand for travel by a greater percentage than the percentage change in price.

While this finding is consistent with prior research using the 2001 NHTS (-1.48 in Weatherford (2011) and -1.79 in McMullen, Zhang, and Nakahara (2010)), these values are more elastic than has been found in other studies of the price elasticity of VMT. A meta-analysis of 43 studies of gasoline and travel demand finds that the price elasticity of demand for gasoline typically has an absolute value of less than 1 or is "inelastic" (Brons et al. 2008). Inelastic means that consumers are not very sensitive to changes in price. Inelastic consumers will reduce their demand for travel by a percentage that is less than the percentage change in price. The NHTS provides a single year of data, with limited variation in price and, of course, no variation over time for a household. By pooling the data, there is greater variation in price with respect to observed VMT and the regression finds that less of the variation in VMT is attributable to changes in price. In comparing the coefficients in the third column of Table 3.2 with the first and second, the coefficient on the price variable, the price elasticity, is lower while some other coefficients, especially the "household types", are higher. Also, more of the variation in VMT is attributable to unobserved factors in the pooled model as the R^2 is lower. The absolute value of the price elasticity estimated using the pooled data is 0.45, a value that is far closer to, yet still more elastic than, the consensus long-term price elasticity of 0.22 (Parry and Small 2005).

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[23] Pooling the data means to make statistical estimations using two, or more, sets of data. Various model specifications were examined. Model specifications that included a dummy variable for the survey year were rejected because the estimated price elasticity is elastic when a survey year dummy variable is included and inelastic when it is not. As discussed in the text above, an inelastic price elasticity of demand was desired. Refinements to the model specification should be considered in later research using the NHTS data to address the topic.

[24] The change in the price of travel causes the household's budget constraint to change. The model estimated here calculates how much the "Marshallian" demand for travel changes given the household's observed characteristics. The price elasticity derived from this demand function may be specifically referred to as the Marshallian or "ordinary" elasticity (Oum et al. 1995, pp. 20-21). This model underestimates changes in consumer surplus. An alternative approach, as discussed in Chapter 4, would better capture the supply and demand of vehicles and fuel in the economy and more completely estimate changes in consumer surplus as a consequence of the changes in tax policy.

[25] A price elasticity of a normal good is negative; as the price increases, demand decreases. For convenience, the absolute value is used so that a "higher" value is intuitively "more elastic."

A growing body of research suggests that price elasticity is not constant among households (Blundell, Horowitz, and Parey 2011). Particularly relevant to this study are research demonstrating that households with lower incomes are more price elastic than households with higher incomes (Wadud, Graham, and Noland 2009; Bento et al. 2009; West 2005).[26] This can be incorporated into the model developed here by adding a term that allows price to interact with income (Zhang et al. 2009; McMullen, Zhang, and Nakahara 2010; Weatherford 2011). The price elasticity is now a function of the natural log of income and the coefficients on the natural log of price variable and the interaction term. Price elasticity has also been shown to vary with other socio-economic variables and population density (Bento et al. 2009; West 2005).

The model is also biased because vehicle choice is endogenous. The choices of whether to own a vehicle, what type (truck or car, for example), how many vehicles of each type to own, and how much to drive each vehicle are all separate decisions that households must make. Household socioeconomics and geography predict these choices and, by not separately modeling those choices the estimates are biased. The model compounds this problem by then holding current vehicle ownership, and the proportion of household VMT per vehicle, fixed. This approach was chosen to avoid the need to make certain simplifying assumptions, discussed in greater detail later in this chapter, which would have prevented the disaggregation of households by certain socio-economic details. This modeling approach is also relatively simple, the results are easier to interpret, and requires no additional data in addition to the NHTS data. However, the resulting endogeneity bias overestimates the price elasticity of demand for VMT.

To minimize this bias, the price elasticity is allowed to vary with characteristics of the household's vehicle stock. Households that own different types of vehicles have been found to be less sensitive to changes in price (McMullen, Zhang, and Nakahara 2010; Weatherford 2011). For this study, three variables are interacted with price. This specification, in Equation 3.2, allows household price elasticity to vary with the number and the fuel economy of the vehicles owned by each household:

$$\begin{aligned} \ln M_i = \alpha &+ \beta_1 \ln p_i + \beta_2 \ln Y_i + \beta_3 \ln V_i + \beta_4 \ln Dist_i + \beta_5 \ln Density_i + \beta_6 W_i \\ &+ \beta_7(\ln p_i * \ln Y_i) + \beta_8(\ln p_i * MPG_i) + \beta_{V2} \ln p_i + \beta_{V3} \ln p_i \\ &+ \beta_{MULTI} + \beta_{TRANSIT} + \beta_{HH\_TYPE} + \beta_{LIFECYCLE} + \beta_{STATE} + \varepsilon_i \end{aligned} \qquad (3.2)$$

where:

$\ln p_i * MPG_i$ is the percentage difference in MPG between the most and least efficient vehicles in household *i* interacted with the natural log of household *i*'s price per mile, and

β_{V2} & β_{V3} are two parameters on the natural log of price per mile that are estimated if household *i* owns 2 vehicles or 3 or more vehicles.

The fourth column of Table 3.2 reports the fitted coefficient values and their robust standard errors for the model with price interactions fitted using the pooled NHTS data. All of the coefficients are statistically different from zero at a 1 percent significance level.

In this model there are 5 variables with price as a component. Consequently, it is incorrect to simply interpret β_1 as the price elasticity. The price elasticity of demand for VMT now varies by household with income and characteristics of the household's vehicle stock. The price elasticity is

[26] Blundell et al (2011) find that price elasticity may not vary with income monotonically and that both low income households and high income households have lower price elasticities than do middle income households. This suggests that price increases may make the fuel tax or MBUF more regressive than estimated in this study.

Table 3.2 Table of Coefficients

	Linear Model Without Price Interactions			Interact Price
Variable	**2001-02**	**2008-09**	**Pooled**	**Pooled**
log(price per mile)	-1.35	-1.28	-0.45	-1.69
	(0.05)**	(0.03)**	(0.01)**	(0.14)**
log(annual income)	0.13	0.09	0.12	0.30
	(0.01)**	(0.01)**	(0.01)**	(0.03)**
log(number of vehicles)	0.73	0.73	0.68	0.79
	(0.06)**	(0.04)**	(0.03)**	(0.03)**
log(great circle distance to work)	0.05	0.03	0.06	0.06
	(0.01)**	(0.00)**	(0.00)**	(0.00)**
log(residential density)	-0.05	-0.05	-0.04	-0.04
	(0.00)**	(0.00)**	(0.00)**	(0.00)**
Number of workers	0.06	0.05	0.03	0.04
	(0.01)**	(0.01)**	(0.01)**	(0.01)**
log(price)*log(income)				0.09
				(0.01)**
log(price)*log(MPG ratio)				0.20
				(0.01)**
log(price)**V2* = 1 if 2 vehicles				0.35
				(0.03)**
log(price)**V3* = 1 if 3 or more vehicles				0.42
				(0.03)**
Multi = 1 if more than 1 vehicle type	0.18	0.14	0.07	0.08
	(0.02)**	(0.01)**	(0.01)**	(0.01)**
Transit = 1 if used transit in past month	-0.04	-0.06	-0.04	-0.04
	(0.02)**	(0.01)**	(0.01)**	(0.01)**
Lifecycle1 = 1 if there are children	0.08	0.12	0.08	0.08
	(0.01)**	(0.01)**	(0.01)**	(0.01)**
Lifecycle2 = 1 if all members retired	-0.23	-0.18	-0.26	-0.25
	(0.02)**	(0.02)**	(0.01)**	(0.01)**
Constant	4.66	5.78	6.91	4.27
	(0.35)**	(0.11)**	(0.12)**	(0.34)**
Observations	19,659	125,936	145,595	145,595
R-squared	0.56	0.56	0.51	0.52

Notes: The dependent variable is log(annual VMT). Robust standard errors are in parentheses. Coefficients for the household vehicles/adults groups dummy variables and the state fixed effects are not displayed for space considerations and are jointly significant at the 1 percent significance level in all four specifications.
* significant at 5 percent; ** significant at 1 percent.

calculated by taking the partial derivative of the demand function in Equation 3.2 with respect to price as shown in Equation 3.3:

$$\frac{\partial \ln M_i}{\partial \ln p_i} = \beta_1 + \beta_7 \ln Y_i + \beta_8 \ln MPG_i + (\beta_{V2} + \beta_{V3}) \tag{3.3}$$

Each household has only one of the parameters β_{V2} & β_{V3} factor into their price elasticity depending on the number of household vehicles (with no parameter for a household with only one vehicle).

The mean price elasticity is -0.43, a value that is close to the β_1 coefficient in the linear model fitted with pooled data, as is expected. The most elastic value is -0.98, which is still inelastic, and the maximum value is 0.02. A positive value for price elasticity is somewhat unexpected because it means that these households increase VMT as the price of driving increases. 137 observations, representing less than 0.1 percent of the population, have a positive price elasticity. The distribution of price elasticity in the population, as illustrated in Figure 3.1, is bi-modal. This is not directly attributable to income but, as illustrated in Figure 3.2, to vehicle ownership. The predicted price elasticities for households with more than 2 vehicles lie predominately between zero and the average, while the predicted price elasticities for households with one to two vehicles lie predominately between the average and -1. Household vehicle ownership is associated with many correlated factors including income, unobserved derived demand for travel, and characteristics of the built environment (such as the density of development, availability of parking, urban traffic congestion, and access to alternative modes of travel).

It is difficult to interpret the results, however, and the reader should not mistake correlation, in this case, with causality. Household demand for VMT is the product of land use, income (including the price of travel relative to the prices of all other consumer goods), and household preferences and consumption, which are all factors that are imperfectly or indirectly measured by the NHTS instrument.

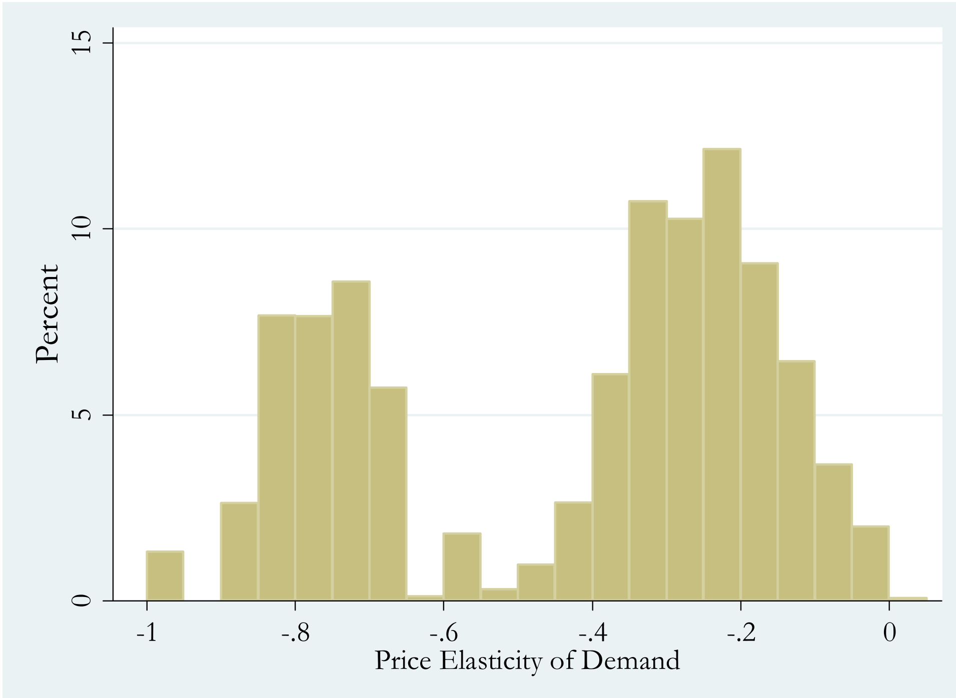
Predictors of Household Demand for VMT

This section describes each of the predictors of household demand for VMT. The reasoning for including each variable is discussed as well as the expected and actual effect on the demand for travel. The expected and actual effect on the estimated price elasticity of variables that are interacted with the natural log of price is also discussed. The technical details regarding how each variable was constructed is assumed to be of interest to a limited audience and these are provided in the Technical Appendix.

Price per Mile

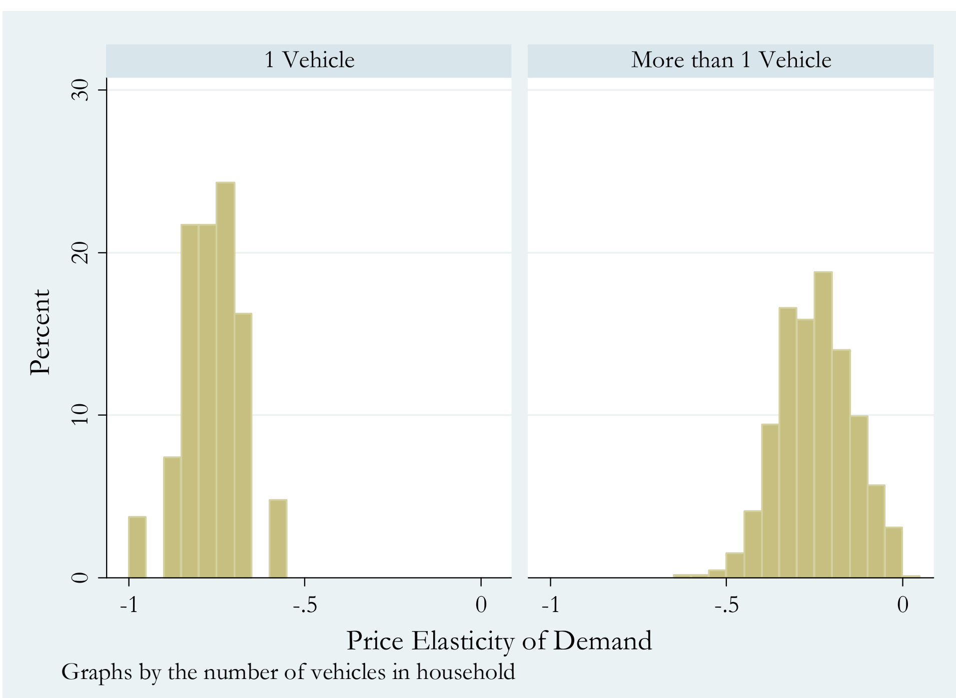
The price per mile of travel is a composite variable based on the VMT-weighted average fuel price of household vehicles divided by the VMT-weighted average household MPG. The price is disaggregated into the cost of fuel and state and federal taxes in order to facilitate the distributional analysis of alternative tax policies (in which the federal and state fuel excise tax rates are either increased or, depending on the alternative being assessed, replaced by or supplemented with MBUFs of various rates and designs). In fitting the model, however, the current retail prices, as reported in the NHTS data are used to calculate this variable.

Figure 3.1 Distribution of Price Elasticity Estimates, 2008-09



Note: This distribution is from the 2009 NHTS with 125,936 weighted observations. The width of each bin is 0.05. The distribution of price elasticity for households in 2001-02 is similarly bi-modal.

Figure 3.2 Distribution of Price Elasticity Estimates by the Number of Household Vehicles, 2008-09



Note: As in Figure 3.1, the width of each bin is 0.05. In 2008-09, 32 percent of households owned only one vehicle.

Retail gasoline prices are added to the NHTS by the EIA from the *Motor Gasoline Price Survey*, an EIA-conducted survey of retail fueling stations (US EIA 2011c). Retail diesel prices are added from a separate survey, the *On-Highway Diesel Fuel Price Survey*, which has poorer geographic resolution.[27] Prices were matched to household vehicles based on survey date and ZIP code by the EIA and are made available in the standard NHTS data sets. As retail prices, these include all federal, state, and local taxes which, in addition to the motor fuel excise taxes, may include sales taxes depending on the fueling station in the sampling frame. The average retail fuel price in 2008-09 is \$3.08 per gallon, including taxes, with a distribution that ranges from \$2.85 to \$3.83 per gallon. Price per mile is calculated by dividing by MPG. In 2008-09, the minimum price is 4.4 cents per mile and the maximum price is 53.4 cents per mile.[28] The weighted average price is 15.3 cents per mile.[29]

Excluded from the household price per mile are several important, but unobserved, costs. These include maintenance, motor oil, tires, vehicle depreciation, insurance, the occupants' value of private risk, and the occupants' value of time. The costs are challenging to measure consistently across households because they vary with the cost, weight, and the age of the vehicle (Bento et al. 2009). The Automobile Association of America (AAA) uses a proprietary methodology to calculate many of these costs for various types of automobiles (AAA 2011). Unfortunately, the methodology changes periodically so that current values are inconsistent with prior estimates. The approach used in this study, to exclude these costs, is consistent with much of the literature (Walls and Hanson 1996; Parry and Small 2005; McMullen, Zhang, and Nakahara 2010; Weatherford 2011).[30]

Annual Income

Annual income is estimated by the household respondents and it is not a binding constraint on annual travel expenditures. A household may spend more on travel in a year than household income and, indeed, 551 observations in the 2009 NHTS do spend more. A household with a lot of VMT relative to their income may have made an error in estimating their income, may have large wealth but low income, or may be borrowing against expected future income. In the NHTS, income is a categorical variable that is converted to a continuous one by taking the median value of each category. The details are provided in the Technical Appendix.

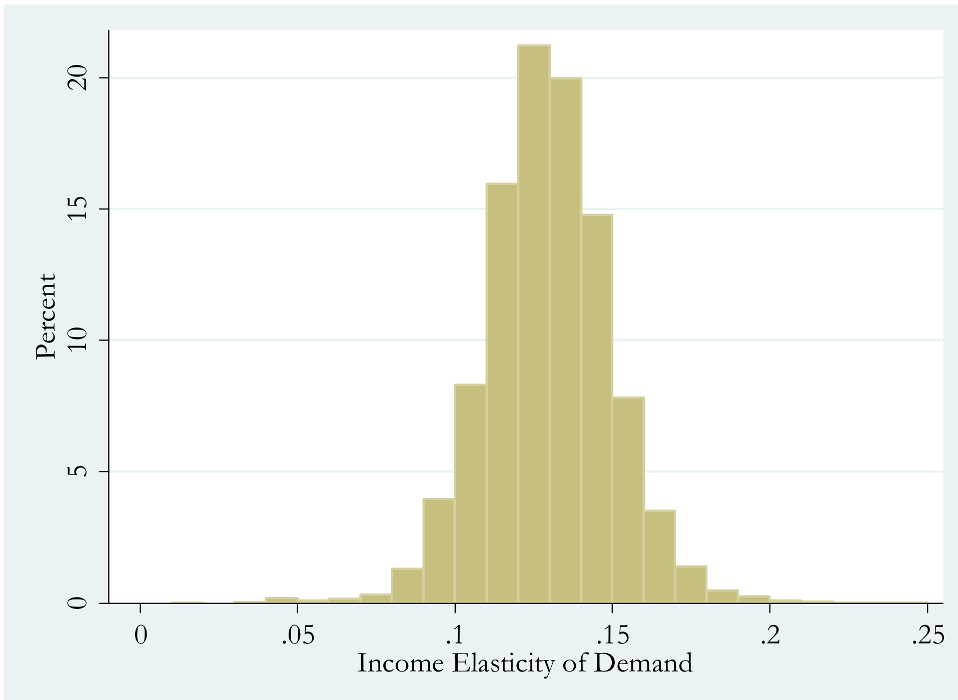
The expected sign of the coefficient of income is positive. Households with higher incomes, controlling for the number of workers, generally own more vehicles and travel more per vehicle than household with lower incomes. In a log-linear econometric model, the coefficient on the natural log of income, β_2, may be interpreted as the elasticity of demand with respect to income. This specifies the percentage change in VMT given a percentage change in income. However, price is also interacted with income in the full model that is specified in Equation 3.2. The income elasticity of demand for travel is calculated by differentiating demand with respect to income as in Equation 3.4:

$$\frac{\partial \ln M_i}{\partial \ln Y_i} = \beta_2 + \beta_7 \ln p_i \tag{3.4}$$

[27] Retail gasoline prices are matched to stations at the ZIP code level while diesel prices are only available at the Petroleum Administration for Defense District (PADD) level, of which there are only 5.
[28] The most fuel efficient vehicles are Honda Insight and Toyota Prius. The least fuel efficient vehicles are recreational vehicles (RV).
[29] Because the range prices are less than \$1/mile, the values are negative when then are transformed logarithmically.
[30] There are some notable exceptions. In light of the difficulty of estimating these costs noted above, Bento et al. (2009) attempt to include maintenance and repair costs using a multiplier on per mile fuel costs, setting the multiplier at "90 percent of per mile gas costs for 2001-2002 autos, 95 percent for 1999-2000 autos, 100 percent for 1995-1998 autos, 105 percent for 1990-1994 autos, and 110 percent for pre-1990 autos."

This expression illustrates that the income elasticity is a function of the natural log of price.[31] The mean income elasticity is 0.13 with a minimum value of 0.02 and a maximum value of 0.24. This range is consistent with other research findings (West 2002, 2005; Bento et al. 2009). The distribution of the income elasticities are illustrated in Figure 3.3.

Figure 3.3 Distribution of Income Elasticity Estimates, 2008-09



Note: The width of each bin is 0.01.

Annual household income is held fixed in the initial distributional analysis of MBUF alternatives and the income elasticity does not have a direct effect on the change in VMT as the ordinary price elasticity includes the income effect. The estimated income elasticities are relevant in the second stage of the analysis when the distributional implications are projected over the years 2010-2030 and incomes grow under various scenarios.

Number of vehicles

The number of vehicles owned by a household is treated as a continuous variable in the model. The number of vehicles is an important predictor of VMT, but also one that is strongly correlated with other predictors of VMT, such as income and the number of workers. It would be incorrect to draw strong causal conclusions about the relationship between the number of household vehicles and the demand for VMT from this regression model. It is appropriate, however, for predicting small changes in VMT resulting from small changes in price (McMullen, Zhang, and Nakahara 2010; Weatherford 2011; Zhang and Methipara 2011).

The number of vehicles is positively correlated with VMT. While the number of vehicles is continuous in this variable, households with more than 7 vehicles are all rounded down to a maximum of eight. As shown in Table 3.3, less than 1 percent of households own more than six

[31] The natural logarithm of the prices per mile, which are in dollars, are negative values.

vehicles. Households with two or three vehicles have a higher average VMT per vehicle than households with only one vehicle. However, this trend falls as the number of vehicles increase. There is clearly a positive relationship between the number of vehicles and total household VMT. While some households with many vehicles may be large with many workers and children, others may just own a collection of motorcycles or antique cars, for example, and the relationship between the number of vehicles and VMT begins to weaken after six or seven vehicles. Therefore, the ratio of vehicles to adults is also an important, separate, predictor of VMT.

Table 3.3 Number of Vehicles per Household, 2008-09

Number of Vehicles	Percent of Population	Average VMT	Average VMT/Vehicle
0	8.6	0	0
1	32.3	10,690	10,690
2	36.3	23,970	11,985
3	14.4	34,376	11,459
4	5.4	42,638	10,659
5	2.0	49,604	9,921
6	0.7	56,587	9,431
7	0.2	66,384	9,483
8 or more	0.2	73,327	9,166

The primary limitation of this model is the bias introduced by not directly accounting for the fact that vehicle choice is endogenous. This approach was deliberately chosen because it is relatively simple, easier to interpret the results, and requires no additional data. Most importantly, this model preserves the detail on the number and range of household vehicle characteristics that is available in the NHTS. A multinomial logit model that would simultaneously model household vehicle and modal choices would require more assumptions and simplifications that would negate the value the detail of the NHTS data (West 2005; Valluri 2008; Bento et al. 2009).

To partially address this limitation, the natural log of price is interacted with the number of vehicles and the relative fuel economy of the household's primary vehicle, which is discussed below. In examining the relationship between the number of vehicles in a household and the estimated price elasticity of that household, it was found that a household with two vehicles is significantly less elastic than a household with one, and a household with three vehicles is even less elastic. There is little change in the elasticity in households with more than three vehicles. Various specifications were considered to model this non-linear relationship.[32] The final approach, to interact the natural log of price with two dummy variables indicating the number of household vehicles, is appealing because it is straightforward and statistically significant. The first dummy variable equals one if a household owns 2 vehicles and the second dummy variable equals one if the household owns more than 2 vehicles. Both dummy variables equal zero for households that own only 1 vehicle.

Great Circle Distance to Work

The household's distance to work, a continuous variable, is the "great circle" distance between the household's home address and work address (US FHWA 2011). In cases where more than one worker resides in a household, the longest distance is used. "Great circle" describes the

[32] Other model specifications considered included interacting the natural log of price with the continuous number of vehicles variable, creating separate dummy variables for additional number of household vehicles (3, 4, 5, 6, and more than 6 vehicles), and with the household type set of indicator variables discussed below.

method used by FHWA to calculate the shortest distance between two points on the surface of a sphere (the surface of the earth). Households that must travel further to get to work have a higher annual VMT than households with a shorter distance to work.

Population Density

Household population density is the Census tract-level density measured by population per square mile (McGuckin 2011). This variable is treated as a continuous variable but is reported categorically as shown in Table 3.4. Households located in a more densely populated area typically travel shorter distances and have better access to mass transit than households located in less densely populated areas. Consequently, households located in relatively dense areas have a lower annual demand for VMT than households located in more sparsely populated areas.

Table 3.4 Distribution of Households by Population Density, 2008-09

Value of Population Density Variable	Actual Population per Square Mile	Percent of Population	Average VMT
50	0-99	11.6	28,669
300	100-499	13.5	25,984
750	500-999	8.0	23,155
1,500	1,000-1,999	12.4	22,161
3,000	2,000-3,999	18.9	20,528
7,000	4,000-9,999	23.4	18,460
17,000	10,000-24,999	7.7	14,860
30,000	25,000-999,999	4.5	7,555

Population density is related to where a household is located along the "urban/rural continuum" which designates four types of communities: urban, second city, suburban, or town and country (rural). These community type designations are one of the key groups for which the distributional implications of the MBUF alternatives are evaluated.

Number of Workers

The number of workers in a household is a good measure of household size with respect to the demand for VMT but most households have less than 3 workers. As shown in Table 3.5, there is a positive relationship between the number of workers and annual VMT. The number of workers is treated as a discrete variable in the model and is not transformed logarithmically. Other measures of household composition are also controlled for, as described below.

Table 3.5 Number of Workers per Household, 2008-09

Number of Workers	Percent of Population	Average VMT
0	25.0	10,462
1	43.4	19,117
2	26.4	30,051
3	4.3	42,461
4	0.8	50,563
5	0.1	51,338
6	0.0	68,352

MPG Difference between Household's Most and Least Efficient Vehicles

In this model, households are not allowed to change the number or type of vehicles owned and how much these are driven in response to changes in tax policy. Further, in households owning more than one vehicle, the share of annual VMT per vehicle is held constant. These are very strong assumptions made to simplify the model that may or may not be reasonable. In fact, they may be reasonable assumptions given the relatively small change in the price per mile for most households for most of the alternatives. Households with more than one vehicle do have more short-run flexibility that other households do not have and may be less sensitive to changes in price. It was previously demonstrated that households with more than one vehicle have lower price elasticity. This variable shows that households with vehicles of various fuel efficiencies have a "substitute" that allows them to be less sensitive to changes in price because they can switch some driving to other vehicles should the price increase or, for that matter, decrease. Instead of explicitly modeling how much each household chooses to drive each vehicle, this model uses an interaction term to allow the price elasticity to vary.

In previous research, a dummy variable has been used to indicate whether a household owns a "substitute" vehicle. This variable is set equal to one if a household owns more than one type of vehicle, for example an SUV and a pickup. This dummy variable is interacted with price and has the effect of reducing the price elasticity of demand (McMullen, Zhang, and Nakahara 2010). While multiple types of vehicles are positively correlated with VMT, the interaction term is not statistically significant in McMullen, Zhang, and Nakahara (2010). This may be because the type of vehicle is not a very good predictor of MPG; there are fuel efficient small pickups and fuel inefficient sports cars, for example. The range of fuel efficiency is particularly large among automobiles. Therefore a household can have a legitimate MPG substitute with two cars while another that owns a van and a SUV may not have a legitimate MPG substitute.

Weatherford (2011) proposes an improvement to this approach by introducing a second dummy variable indicating whether or not a household owns two or more vehicles where the MPG of one of the vehicles is 20 percent or more fuel efficient than the average MPG of the household. This variable more clearly indicates whether or not the household has a vehicle that is more, or less, fuel efficient than the others owned by the household, regardless of type. It is problematic, however, in that the 20 percent threshold is arbitrary.

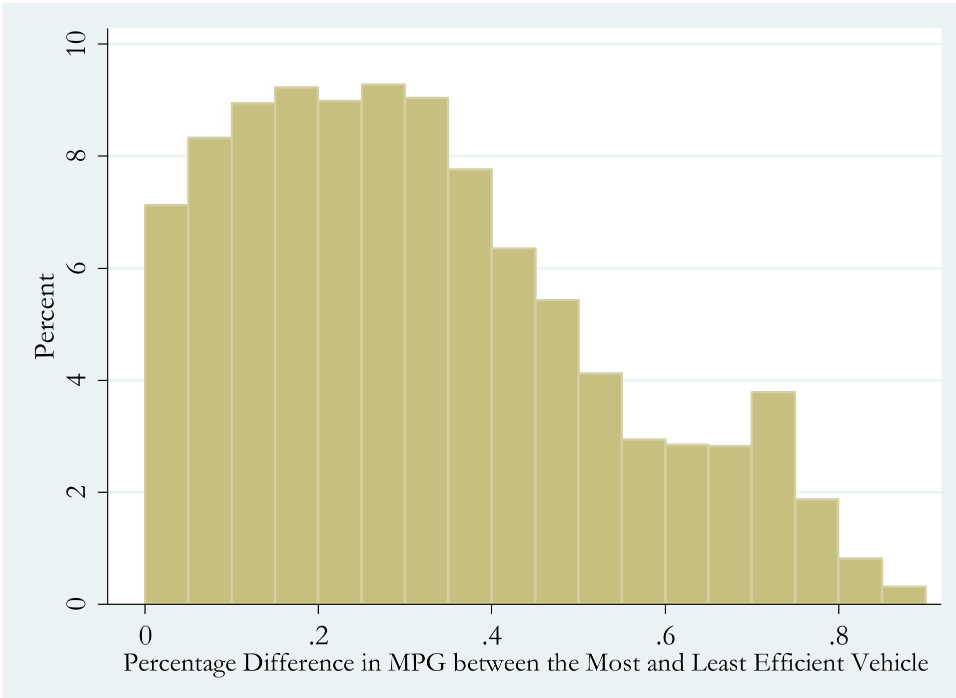
This study introduces a continuous alternative to the MPG "substitute" variable in using the percentage difference between the most fuel efficient and the least fuel efficient vehicle in the household. This household MPG range variable addresses both of the concerns raised above and indicates not only whether a household owns a vehicle that is a "substitute" based entirely on MPG criteria, but also captures how good a substitute that vehicle is. Because the price elasticity works in both directions, it is important to use a variable for which the coefficient will always have the same sign.

The percentage difference is calculated by dividing the MPG of the household's least efficient vehicle from the MPG of the household's most efficient vehicle and then dividing that difference by the MPG of the most efficient vehicle. For this variable, 36 percent of households have a value of zero because they either have only one vehicle or, in relatively rare cases, have two vehicles with the same MPG.[33] The distribution of this variable, in Figure 3.4 shows that many households with two or more vehicles have a non-trivial difference in the fuel economy between their most and least fuel efficient vehicles. The percentage difference in MPG between the most and

[33] Only 345 observations with a value of zero for this variable, less than 1 percent, own two or more vehicles.

least fuel efficient vehicle is greater than or equal to 20 percent in two thirds of households with more than one vehicle and 39 percent of all households.

Figure 3.4 Distribution of the Percentage Difference in MPG between the Most and Least Efficient Vehicle, Excluding Values of Zero, 2008-09



Note: The width of each bin in the histogram is 0.05.

Multiple vehicle types

While the dummy variable for multiple vehicle types is not used in this model to signify the availability of a substitute vehicle, and is not interacted with price as in McMullen, Zhang, and Nakahara (2010) and Weatherford (2011), it is nonetheless a statistically significant predictor of VMT. There is a positive correlation between owning more than one type of vehicle and annual VMT.

Used transit in the past month

Households that use transit, even infrequently, drive less than households that never use transit. This variable indicates whether any household member used an alternative mode of transportation at least once in the past month (excluding walking, biking and several other exceptions). This variable indicates that the household has access to an alternative to their private automobiles and occasionally (or frequently) uses the alternative. This results in lower annual VMT. While the coefficient on this dummy variable is very significant, and other research has shown that access to transit may increase a household's price elasticity, the coefficient of an interaction between this variable and price was not significantly different from zero at a 5 percent level of confidence and is not included in the model.

Ratio of adults to vehicles

As discussed above, the number of vehicles and workers in a household are each important predictors of demand. However, it is also important to account for the ratio of vehicles to adults. VMT is increasing with both vehicles, as we have discussed above, and with adults, which follows logic. This variable categorizes each household into 9 types, 10 if households without any vehicles are included, based on the number of vehicles owned (1, 2 or more than 2) in different household sizes (1, 2 or more than 2 adults).

Table 3.6 displays the proportion of households in each vehicle to adult category type. In addition, the coefficients for these variables are included, along with their robust standard errors because these were omitted from Table 3.2 for space constraints. All are significant at the 1 percent level of statistical significance with pooled data in the model with price interactions.[34] The coefficients, along with the mean VMT for each category, clearly show that VMT is increasing jointly with the number of vehicles and the number of adults.

Table 3.6 Coefficients For the Vehicles to Adults Household Type Variable

Number of Vehicles	Number Of Adults	Percent of Population	Average VMT	Coefficient	Robust St. Error
0	all	8.6	0	-	-
1	1	20.6	10,196	0	(1)
1	2	10.0	11,633	0.16	0.02
1	3 or more	1.7	11,527	0.20	0.05
2	1	3.7	19,050	0.98	0.08
2	2	29.0	24,482	1.15	0.07
2	3 or more	3.6	25,224	1.22	0.08
3 or more	1	1.9	31,500	1.27	0.09
3 or more	2	12.9	36,389	1.33	0.08
3 or more	3 or more	8.8	44,266	1.40	0.08

Note: (1) The model would be over-specified if this coefficient was estimated.

Life cycle groups

These two categorical variables (condensed from ten groups of life cycle type) control for households with children and households comprised entirely of retired adults.[35] Households with children, comprising 35 percent of households, have a much greater demand for VMT than other households. Retired households, in contrast, have a much lower demand for VMT. Retired households comprise 27 percent of the population in 2008-09. This is an increase from 2001-02 when retired households comprised 24 percent of the population. The differences in the travel behavior, and vehicle characteristics, between households in different lifecycle stages have important equity implications as well. It is also significant that these statistics reflect the aging of the American population as well as the increasing mobility of older Americans. The average VMT of retired households has increased from 13,164 in 2001-02 to 13,798 in 2008-09. This was during a period when, as previously noted, other households were reducing VMT due to higher travel costs and lower incomes.

[34] The variables are not all individually significant at this level in the model without interactions but they are all jointly significant at the 1 percent level of statistical significance.

[35] More information on the ten original life cycle groups and the details on the construction of this variable are available in the Technical Appendix.

State fixed effects

There are differences between states that may affect the demand for VMT. These can include weather, road quality, characteristics of the built environment which are not captured in other variables, and state laws, fees, and regulations among other unobserved factors. The state fixed effects are jointly statistically significantly different from zero at a 1 percent confidence level.

4. METHODOLOGY

OVERVIEW

This dissertation analyzes the distributional implications, and other equity considerations, of adopting alternative MBUF policies. The first phase of the analysis estimates changes in household VMT, fuel consumption, tax, and welfare for several federal and state MBUF policy options. The distributional implications of these are compared to current fuel tax policy and to each other. The various options, discussed in detail in the following section of this chapter, were selected to examine how the distributional implications of MBUFs may vary with the rate level and rate structure.

The second phase of the analysis projects the distributional implications of several policy options over years 2015 to 2030 under various scenarios. This part of the study examines how the distributional implications might change under alternative future macroeconomic conditions and future improvements in vehicle fuel economy. These scenarios are based on EIA assumptions and projections.

DISTRIBUTIONAL ANALYSIS OF ALTERNATIVES

This section describes the methodological approach for estimating and then comparing the distributional implications, and other equity considerations, of various MBUF policy options. Eight tax policies are analyzed. Each alternative increases or decreases the per-mile cost of driving, hereafter referred to as the "price" per mile of driving, for each household. The fitted model, described in Chapter 3, is used to predict a new annual household VMT given the new prices for each alternative. Changes in the annual tax, consumer surplus, and welfare of each household are calculated based on these predictions of VMT. The changes are analyzed to characterize the potential distributional implications of adopting an MBUF.

Alternative Tax Policies

These eight tax policy options alter the price per mile of travel for each household with marginal impacts on annual household VMT and tax. Each of the policy options explained below increases or decreases the price per mile of travel for each household based on the fuel efficiency of their household's vehicles. The price per mile variable in the fitted model is recalculated and then the model is used to estimate the changes in annual VMT, tax and consumer surplus. In addition, the net change in national VMT, tax revenue, tax administration, collection, and enforcement costs, and travel related externalities are also calculated for each of the policy options.

Equivalent Flat Rate MBUFs

The first three policy options examined in this study are state and federal "flat-rate" MBUFs set at rates that are equivalent to the current state and federal fuel taxes.[36] The "equivalent" rate is calculated for each jurisdiction by dividing total gasoline tax revenue by total VMT. This approach differs slightly from a prior study by Weatherford (2011) that calculated a perfectly revenue-neutral tax rate, but it is consistent with other related research (McMullen, Zhang, and Nakahara 2010).[37] These equivalent flat-rate MBUFs allow the distributional implications of replacing the per-gallon

[36] A "flat-rate" MBUF means that all vehicles are charged the same rate per mile. Freight trucks are outside the research scope but it is likely that they would be subject to separate policies following current practice.

[37] The equivalent rate method differs from the revenue-neutral method in that total revenue collected may slightly increase or decrease with net changes in total VMT and fuel consumption. The equivalent tax rate is also much easier to calculate than the revenue-neutral tax rate. In this study, annual federal tax revenue, ignoring any change in collection costs, is reduced by $25.1 million; 0.12 percent of the estimated $21.8 billion collected from households in 2008-09.

gasoline tax with a flat per-mile tax on VMT to be examined separately from the distributional implications of a rate increase or other changes in rate structure.

Alternative 1: Replace the federal fuel tax with an equivalent flat-rate MBUF

This policy option replaces the per-gallon federal fuel tax with a flat-rate per-mile tax in the calculation of each household's price per mile. The fuel tax rate for most households is 18.4 cents per gallon. Households that own diesel vehicles are taxed at a higher rate per mile, however. The fuel tax rate for these households ranges from 18.5 to 24.4 cents per gallon depending on the proportion of total household VMT contributed by the diesel vehicles. Table 4.3 shows how the distribution of price per mile changes under this alternative along with all of the other alternatives.

The equivalent flat-rate is calculated by dividing the total annual tax paid by households by total annual household VMT:

$$\frac{\sum_{i=1}^{n}\left(\mathrm{w}_i \cdot \text{tax rate}_i \cdot \text{gallons}_i\right)}{\sum_{i=1}^{n}\mathrm{w}_i \cdot \mathrm{VMT}_i} = \frac{\$21{,}800{,}000{,}000}{2{,}390{,}000{,}000{,}000} = \$0.0091 \qquad (4.1)$$

where w_i is the sampling weight for each household, *i*, in the 2009 NHTS with a sample size, *n*, of 152,756. In this first policy option, the federal fuel tax component of the household price per mile is set at 0.91 cents per mile.

Alternative 2: Replace state fuel taxes with equivalent flat-rate MBUFs

This policy option replaces the per-gallon state fuel tax component each household's price per mile calculation with a flat rate per-mile tax that is specific to the tax rate of each state. For this alternative, only the per-gallon state excise taxes reported in Table MF-205 in the FHWA *Highway Statistics* publication are replaced (US FHWA 2010). Retail fuel prices often include additional state and local sales taxes and other taxes which may or may not be hypothecated for transportation spending. Only state fuel taxes are replaced because the publically available historical data on other tax rates, details on how they are applied and when they came into effect are incomplete and occasionally inaccurate (US FHWA 2010). Local taxes are especially problematic. Not only are the data challenging to validate, but the public-access NHTS doesn't have the geographic resolution to enable an accurate assignment of a household to an appropriate local jurisdiction. The effort of obtaining geo-coded NHTS data and completely validating local fuel and sales tax rates may not necessarily be worthwhile, however, because households could strategically choose to purchase gasoline outside of the locality where they reside in order to avoid paying a higher tax rate.[38]

Removing fuel taxes will reduce the amount of sales taxes in at least five states where the fuel tax is subject to sales tax causing the change in price to be incorrect by a small percentage.[39] States considering adopting an MBUF should, obviously, model the effects more carefully. However, as will be demonstrated in the sensitivity analysis in Chapter 5, the results of this study appear to be sufficiently robust to provide general guidance on equity considerations regardless of this limitation.

The equivalent flat-rate MBUF rates specific to each state are calculated as in Equation 4.1 using the total tax collected and VMT in each state. The calculated equivalent MBUF rates, along with the current fuel tax rates, are shown in Table 4.1.

[38] This may also be true at the state level, but I make the reasonable assumption that households purchase motor fuel in the state in which they reside.

[39] The five states which may not have exempted the fuel tax from sales tax in the years 2008-09 are California, Connecticut, Georgia, Michigan, and New York.

Table 4.1 2009 State Fuel Tax Rates and Their Real Equivalent Flat-Rate MBUFs

State	**Gasoline Tax** (cents/gallon)	**Diesel Tax** (cents/gallon)	**Flat MBUF, State Rate** (cents/mile)
Alabama	18.5	19.6	0.9
Alaska (1)	8.2	8.2	0.3
Arizona	18.5	26.8	0.9
Arkansas	22.1	23.2	1.1
California	18.5	18.5	0.9
Colorado	22.6	21.1	1.1
Connecticut	25.7	44.7	1.2
Delaware	23.7	22.6	1.1
District of Columbia (2)	24.2	20.6	1.0
Florida	16.6	16.6	0.8
Georgia	7.7	7.7	0.4
Hawaii	17.5	17.5	0.8
Idaho	25.7	25.7	1.3
Illinois	19.6	22.1	0.9
Indiana	18.5	16.5	0.9
Iowa	21.6	23.2	1.1
Kansas	24.7	26.8	1.2
Kentucky (2)	24.8	21.7	1.1
Louisiana	20.6	20.6	1.0
Maine (2)	30.4	31.6	1.4
Maryland	24.2	25.0	1.1
Massachusetts	21.6	21.6	1.0
Michigan	19.6	15.4	1.0
Minnesota (2)	27.9	27.9	1.1
Mississippi	18.9	18.9	1.0
Missouri	17.5	17.5	0.8
Montana	28.6	28.6	1.5
Nebraska (2)	27.6	27.2	1.4
Nevada	24.7	27.8	1.2
New Hampshire	20.2	20.2	0.9
New Jersey	10.8	13.9	0.5
New Mexico	19.5	23.6	1.0
New York (2)	25.9	24.1	1.2
North Carolina	31.1	31.1	1.5
North Dakota	23.7	23.7	1.2
Ohio	28.8	28.8	1.4
Oklahoma	17.5	14.4	0.9
Oregon	24.7	24.7	1.2
Pennsylvania	30.9	39.2	1.5
Rhode Island	30.9	30.9	1.4
South Carolina	16.5	16.5	0.8
South Dakota	22.6	22.6	1.2
Tennessee	20.6	17.5	1.0
Texas	20.6	20.6	1.0
Utah	25.2	25.2	1.2
Vermont (3)	20.6	26.8	1.0
Virginia	18.0	18.0	0.9
Washington	38.6	38.6	1.9
West Virginia	33.1	33.1	1.6
Wisconsin	31.8	31.8	1.5
Wyoming	14.4	14.4	0.8

Notes: All dollar amounts have been adjusted for inflation and are in constant 2010 dollars. (1) Alaska temporarily halted its fuel tax from September 2008 through August 2009. (2) At least five states and the District of Columbia increased their fuel tax rates between 2008 and 2009. (3) Vermont decreased its fuel tax rate. See Tables A.1 and A.2 for detail. Source: US FHWA (2010), Table MF-205, "STATE MOTOR-FUEL TAX RATES, 1996 – 2009".

Alternative 3: Replace both the state and federal fuel taxes with their equivalent flat-rate MBUFs

This policy option replaces both state and federal fuel tax fuel taxes with the equivalent flat-rate MBUFs calculated in alternatives 1 and 2. The distributional implications of these three policy options should be consistent. However, this third option is expected to produce more pronounced effects where changes in the distribution of the tax burden do occur.

Increased Flat Rate MBUF

The next two alternatives compare the distributional implications of a fifty percent increase in the federal tax rate. These policy options are designed to conduct a quasi-experiment that isolates the distributional implications of a rate increase from the distributional implications of replacing a fuel tax with and equivalent MBUF. The fifty percent increase is a realistic but arbitrary policy.[40]

Alternative 4: Increase the federal fuel tax rate by fifty percent

This policy option increases the federal gasoline tax by 50 percent to 27.6 cents per gallon and the federal diesel tax to 36.6 cents per gallon. The price per mile variable is recalculated accordingly for each household.

Alternative 5: Replace the higher federal fuel tax with an equivalent flat-rate MBUF

This policy option calculates the equivalent flat-rate MBUF using Equation 4.1 with the total annual tax paid by households by total annual household VMT estimated with the fifty percent increase in the federal fuel tax rate in alternative 4. The higher fuel tax rate increases the total tax collected by 46 percent to $31.9 billion and reduces total VMT by 1 percent to 2.37 trillion miles. This increases the equivalent MBUF rate from 0.91 cents per mile to 1.35 cents per mile.

Additional Alternative MBUF Designs

The final three options compare alternative MBUF rate structures. The purpose of these options is to examine the distributional implications of plausible alternative rate structures other than an equivalent flat-rate design. This list is not intended to be comprehensive, or even realistic, but rather to efficiently generate sufficient information about the effects of alternative MBUF rate structures on equity.

Alternative 6: Add a 1 cent flat-rate MBUF to the current federal fuel tax

This alternative examines the adoption of an arbitrarily large flat-rate MBUF that increases the amount of revenue collected. By preserving the existing fuel tax, there is no change in the existing incentive for vehicle fuel efficiency provided by the fuel tax. An MBUF is imposed on top of the existing costs of driving and affects all household's driving costs equally on a per-mile basis. The 1-cent MBUF rate has no significance other than being an integer.

Alternative 7: Replace the federal fuel tax with a MPG-based tiered-rate MBUF

MBUF trials conducted around the US to date have not used a flat rate. Instead, drivers are charged an equivalent mileage fee based on their vehicle's fuel economy.[41] However, adopting such a design would not address the deleterious effect of improving vehicle fuel economy on revenues; one of the primary policy concerns motivating the considerations of adopting an MBUF.

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[40] Since the federal gasoline tax was last increased in 1993, the CPI has advanced by 51 percent. Therefore, this fuel tax rate is approximately equal, in constant dollars, to the fuel tax in 1993.

[41] Such a design would also have no distributional implications since it would not change the tax rate per mile.

This alternative is intended to create a price-based incentive for improved fuel economy while not allowing improved fuel economy to erode revenue. This alternative, which has also been referred to as a "green mileage fee" elsewhere in the literature, levies a high MBUF on vehicles whose combined city/highway fuel economy rating falls below a specified threshold and levies a low MBUF on vehicles whose fuel economy exceeds the threshold (Agrawal, Dill, and Nixon 2009). Any threshold could be adopted and it could be adjusted each year as the average fuel economy improves.

For this analysis, the threshold is set at the median EPA fuel economy rating so that approximately half of all household vehicles would have a tax cut and the other half would have a tax increase.[42] In the 2008-09 population of vehicles, the median EPA fuel economy rating is 25.1 MPG. Therefore, for alternative 7, the threshold is set at 25.1 MPG. In this alternative the rates are intentionally extreme; the high rate is set to 2.94 cents per mile, which is the highest federal tax per mile by any household, and the low rate is set to 0.28 cents per mile which is the least federal tax paid per mile by any household. This rate structure is intended to have the opposite effect of the equivalent flat rate MBUF. The distribution of vehicle fuel economy is more or less bell shaped around the mean and the majority of households have "average" fuel efficiency. Therefore, with a single equivalent flat rate, most households will have a very minor change in their price per mile. With the tiered-rate MBUF, most households have either a large increase or a large decrease in their tax rate. The alternative creates an incentive structure where no household with poor fuel efficiency will increase VMT and no household with high fuel efficiency will reduce VMT.

The primary disadvantage of this type of fee is that it creates a "notch" at the point of the threshold (Sallee and Slemrod 2010). There are large benefits to being on one side of this arbitrary disjoint and large costs to being on the other. Were this type of policy to be adopted as proposed in this illustrative alternative, similar to current fuel economy regulations, it would very likely distort the market for vehicles (Sallee and Slemrod 2010; Sallee 2010). In addition to the mean MPG threshold with the extreme rates, five alternatives with higher thresholds and lower rates are considered as specified in Table 4.2. The alternatives use thresholds that are increased by 10 and 25 percent of the median MPG, from 25.1 MPG to 27.6 MPG and 31.4 MPG. With the higher threshold, fewer vehicles will qualify for the low rate. The extreme rates are replaced with lower notional values that are approximately midpoints between the equivalent flat rate and the extreme rate. The lower rates will reduce annual household taxes, relative to the high rates, for all households except those with the most fuel efficient vehicles. With the higher threshold, the 0.5 cent per mile MBUF provides only a small discount to the 0.59 cents, or less, those vehicles were paying with the current fuel tax.[43]

Table 4.2 Alternative Rate Structures for Tiered MBUF Alternative

	Threshold	High Rate	Low Rate
Tiered MBUF	25.1 MPG	2.94 cents per mile	0.28 cents per mile
Alternative 1	25.1 MPG	1.50 cents per mile	0.50 cents per mile
Alternative 2	27.6 MPG	2.94 cents per mile	0.28 cents per mile
Alternative 3	27.6 MPG	1.50 cents per mile	0.50 cents per mile
Alternative 4	31.4 MPG	2.94 cents per mile	0.28 cents per mile
Alternative 5	31.4 MPG	1.50 cents per mile	0.50 cents per mile

[42] The EPA fuel economy rating is used instead of the EIA adjusted on-road fuel efficiency estimate so that this policy affects households based solely on vehicle ownership and not their location and annual VMT.

[43] A vehicle with a fuel economy of 31.4 MPG currently pays about 0.59 cents per mile in federal gasoline tax.

Alternative 8: Replace state and federal fuel taxes with an "optimal" flat-rate MBUF

This alternative is based on the "optimal VMT tax rate" calculated by Parry and Small (2004). An optimal tax is an economically efficient tax with two components; an optimal Pigouvian tax and an optimal Ramsey tax. A Pigouvian tax is based on correcting, or pricing, the social cost of externalities. A Ramsey tax is an efficient tax that is based on the relative price elasticity of different goods that is intended to raise revenue by minimizing deadweight loss.[44] The optimal MBUF calculated by Parry and Small is 17.7 cents per mile and the Ramsey component is 7.4 cents per mile, 42 percent of the total tax.[45] While social welfare might be improved by using the proceeds of the Ramsey tax to eliminate less efficient taxes, such an analysis is well outside to scope of this study. This alternative is intended only to examine the possible distributional implications of an extremely large increase in the price per mile of travel.[46]

Calculating Price per Mile for Policy Alternatives

The household's price per mile of travel is recalculated for each of these alternative tax policies by replacing the current rates with the new specified rates. The distribution of the price per mile for each of the alternatives is summarized in Table 4.3. This table also helps to illustrate how the tax is a relatively small percentage of the total price and that the policy changes increase the price for high MPG households by a greater percentage than low MPG households. The price variables are recalculated to account for the change in the tax rate and the coefficients on the price variables are used to predict the change in household VMT and the change in consumer surplus for each of the alternatives. These results are then used to calculate the change in household taxes and government revenue, gallons of fuel consumed, and externalities.

Table 4.3 Distribution of Price per Mile for Current Fuel Tax and Alternatives

Transportation Tax Alternative	Household Price in Cents per Mile of Travel						
	Min	10th Percentile	25th Percentile	Median	75th Percentile	90th Percentile	Max
Current, 2001-02	3.2	6.3	7.1	8.1	9.2	10.5	49.9
Current, 2008-09	4.4	11.9	13.5	15.3	17.5	19.9	53.4
Flat MBUF, federal only	5.1	12.0	13.5	15.3	17.4	19.6	51.4
Flat MBUF, state only	5.0	12.1	13.6	15.3	17.4	19.6	51.4
Flat MBUF, state & federal	5.7	12.2	13.7	15.3	17.2	19.3	49.4
Increased fuel tax	4.6	12.2	13.9	15.8	18.0	20.5	54.8
Increased flat MBUF	5.5	12.5	14.0	15.8	17.8	20.0	51.8
Add 1 cent MBUF	5.4	12.9	14.5	16.3	18.5	20.9	54.4
Tiered MBUF	4.4	11.6	13.3	16.2	19.0	21.3	53.4
17.7 cent MBUF	21.6	28.0	29.4	31.1	33.1	35.2	65.3

Note: Price includes state and federal tax and the price of fuel.

44 Deadweight loss is a term used in economics to describe the excess burden of a tax that results from the distortion to the free market equilibrium by increasing the price of a good above its efficient price and reducing the quantity demanded below its efficient quantity.

45 The values have been adjusted from year 2000 dollars to year 2010 dollars; the optimal VMT fee in Parry and Small (2004) is 14 cents per mile.

46 Fuel consumption and VMT are better targets of a consumption tax than many other goods because the demand for them is price inelastic. An optimal Ramsey tax is intended to raise revenue more efficiently and the proceeds can be used to eliminate less efficient taxes (Parry and Small 2004). However, this study is not suggesting that a Ramsey should be adopted or that such a tax is a likely MBUF policy option.

Calculating Distributional Implications

Four metrics are used to evaluate the equity implications of the MBUF alternatives:

- The change in annual taxes,
- The Suits index (Suits 1977; West 2005),
- The change in consumer surplus (McMullen, Zhang, and Nakahara 2010; Weatherford 2011),
- The change in welfare (Parry et al. 2005).

This section describes how the metrics are calculated and discusses how they are used in the comparative distributional analysis in Chapter 5.

Calculating the Change in Annual Taxes

Fuel taxes are directly levied on the distributors of motor fuels at the "rack." While households do not directly pay fuel taxes, research has shown that the fuel tax is completely passed on to consumers (Alm, Sennoga, and Skidmore 2009).[47] In contrast, MBUFs will be directly levied on consumers. Households could pass on some of their tax burden to firms should consumers demand lower prices and higher wages to offset a tax increase. Fuel taxes paid by firms in the transport of goods and the provision of services could also be partially passed on to consumers in the form of higher prices. Again, it is unclear whether the change from fuel taxes to MBUFs will impact the incidence of the tax. It is reasonable and convenient to assume that the household's annual fuel taxes are equal to the total number of gallons of fuel consumed multiplied by the fuel tax rate. Likewise, the household's annual MBUF tax is equal to the total annual VMT multiplied by the MBUF rate in each alternative. The change in annual taxes are then calculated for each household by subtracting current annual fuel taxes from the annual fuel and MBUF taxes borne under each of the policy options.

The change in taxes is therefore a relatively uncomplicated, accessible, and broadly appealing metric of the equity implications of these MBUF alternatives. Many elected, appointed and senior civil service decision makers and advocates will first want to know how a proposed change in tax policy increases or decreases their constituents' and customers' annual taxes.

In addition to reporting the change in taxes, the results also report the percentage change and the change in taxes as a percent of income. These metrics are more relevant to understanding equity implications than the dollar change in annual taxes because they place the dollar amount in an appropriate context. The percent change in taxes as a share of income is important with respect to the household's or group's ability to pay, for example. However, the Suits index, described and discussed below, is easier to interpret.

The change in taxes is disaggregated for key groups of households, including:

- Income groups (categorized by thirds and tenths of the population rank ordered by income),
- Household life cycle (retired households and households with children),
- Community types (households categorized into groups, such as urban, suburban and rural, based on the "contextual" population density of the community in which they live (McGuckin 2011)).

[47] The topic of the incidence of fuel taxes was more thoroughly discussed in Chapter 2.

Disaggregating the change in taxes allows for the identification of the winners and losers of each policy alternative. Any large change in the average annual taxes of any group is likely to have a strategic political implication because many groups and constituencies expect to receive federal transportation funding in proportion to their tax burden. Table 4.4 presents the annual VMT, average fuel economy, income, and average annual fuel taxes in 2008-09 for these key groups.

Table 4.4 Summary Statistics For Key Groups, 2008-09

Income Thirds	**Average VMT** (miles)	**Average Income** (dollars)	**Average MPG**	**Average Fuel Tax** (dollars)	**Share of Population** (percent)
Low Income	12,179	16,794	20.7	235.98	33.3
Middle Income	21,653	48,117	21.2	422.57	33.3
High Income	29,524	140,453	21.3	570.79	33.3
Life Cycle Groups					
Household with Children	28,238	83,483	21.1	547.56	34.9
Retired Household	13,798	46,394	20.5	270.49	26.8
Other	19,769	70,232	21.5	381.98	38.3
Community Types (1)					
Urban	13,860	62,539	21.7	252.79	17.6
Second City	18,695	60,331	21.3	352.31	18.1
Suburb	21,061	84,642	21.6	396.00	24.3
Rural	25,438	64,916	20.5	513.08	40.0

Note: (1) "Urban," "Second City," "Suburban," and "Rural" are defined by Claritas, Inc. using the population density of the Census block in which the household is located in the context of the surrounding area.

The changes in the average annual household taxes at the state-level are also examined. There are some caveats regarding statistical significance of the results of smaller states that were not oversampled. The above comments on the strategic political implications of any change in the tax burden of a key constituency holds true for states as well. Members of Congress seek the largest possible share of federal funding for the state or district they represent. This has led to minimum HTF funding guarantees in the name of "equity" (Kirk 2004). Historically, a "donor" state contributes more federal fuel tax revenue to the HTF than it receives in federal transportation revenue and a "donee" state receives more in federal aid than it contributes in fuel tax revenue. However, the General Accountability Office (GAO) reports that since 2005 every state has "received as much or more funding for highway programs than they contributed to the Highway Account of the trust fund" (US GAO 2010, 2).[48] The higher funding levels have not eliminated concerns about equity; members and state officials are instead now concerned about their "relative share" of highway funding. This is the ratio of each state's proportion of total contributions to the Highway Account of the HTF to the proportion of total appropriations (US GAO 2010, 13). Table 4.5 presents the average household fuel economy, annual household VMT, and annual household taxes of each state. In addition, Table 4.5 notes whether the state is a donor or a done according to their

[48] There are several reasons for this. The first is that funds are apportioned about two years before estimates of current contributions can be finalized and, with rising fuel prices and lower VMT, these apportionments have been too high. There are also issues with funding formulas that may compound the problem. The shortfall has resulted in the need to transfer more than $30 billion dollars in general funds to the HTF since 2005. More recently, federal economic stimulus policies in 2008, 2009, and 2010 further increased federal transportation spending above state contributions to the HTF.

Table 4.5 Summary Statistics for States, 2008-09

State	Average VMT (miles/household)	Average Household MPG	Average Fuel Tax (1) (dollars/household)	Relative Share of HTF Funding (2)	Number of Observations
Alabama	24,356	20.4	446.03	104 percent	372
Alaska	20,365	19.3	268.45	429 percent	218
Arizona	19,105	20.3	356.99	91 percent	6,273
Arkansas	20,235	19.9	429.32	103 percent	232
California	20,833	21.7	366.20	91 percent	18,565
Colorado	20,548	20.7	413.46	91 percent	270
Connecticut	21,246	22.3	432.10	135 percent	240
Delaware	21,589	21.8	428.11	164 percent	218
District of Columbia	7,022	21.6	129.70	461 percent	234
Florida	19,586	21.3	325.62	91 percent	13,835
Georgia	24,264	20.9	313.67	91 percent	6,526
Hawaii	16,559	21.3	276.20	182 percent	228
Idaho	23,740	20.5	538.47	143 percent	227
Illinois	19,986	21.8	351.15	92 percent	721
Indiana	22,029	20.9	394.07	91 percent	3,081
Iowa	24,606	20.3	499.75	93 percent	3,363
Kansas	25,757	20.6	556.41	102 percent	228
Kentucky	24,427	20.7	485.55	94 percent	235
Louisiana	22,593	20.9	429.52	93 percent	253
Maine	21,908	21.3	502.50	96 percent	251
Maryland	21,533	22.7	421.93	91 percent	314
Massachusetts	18,994	21.6	356.17	97 percent	350
Michigan	22,390	20.6	425.25	92 percent	564
Minnesota	22,592	21.4	435.45	92 percent	307
Mississippi	32,150	19.9	616.86	92 percent	226
Missouri	22,733	21.3	399.12	97 percent	351
Montana	25,242	20.2	616.06	216 percent	228
Nebraska	25,211	20.2	579.90	100 percent	1,154
Nevada	20,787	20.2	455.39	93 percent	223
New Hampshire	22,934	22.0	404.26	107 percent	235
New Jersey	19,685	21.7	270.00	91 percent	479
New Mexico	16,390	19.9	322.99	108 percent	222
New York	13,809	21.6	280.04	116 percent	14,192
North Carolina	23,182	20.9	566.48	91 percent	9,747
North Dakota	25,612	19.5	577.39	205 percent	226
Ohio	20,877	20.8	471.95	91 percent	625
Oklahoma	21,329	20.0	389.94	97 percent	225
Oregon	17,847	21.4	368.63	101 percent	244
Pennsylvania	18,507	21.6	437.30	116 percent	688
Rhode Island	20,764	22.0	464.54	227 percent	221
South Carolina	22,474	20.5	390.28	91 percent	4,561
South Dakota	27,941	19.7	615.04	201 percent	1,626
Tennessee	23,906	20.8	460.49	91 percent	2,243
Texas	22,916	20.5	446.00	91 percent	19,633
Utah	21,358	20.8	460.61	92 percent	235
Vermont	22,557	22.3	412.88	206 percent	1,507
Virginia	23,765	21.2	417.43	91 percent	13,379
Washington	20,984	21.0	590.18	92 percent	353
West Virginia	23,945	21.2	586.53	166 percent	226
Wisconsin	22,299	21.0	546.83	107 percent	1,516
Wyoming	24,445	18.8	432.96	142 percent	230

Notes: (1) Includes state and federal taxes on the sale of motor fuel, but does not include local taxes.
(2) Donor states, those states whose share of federal-aid transportation funding is less than their share of contributions to the HTF, are highlighted. See US GAO, Figure 6 (2010) and US FHWA, Table FE-221, FY 2008 (2011).

"relative share rate of return from the Highway Account of the Highway Trust Fund, using time-lagged comparison data, apportioned programs, and high priority projects, FY2005-2009" as calculated by the GAO (2010, Fig. 6). While it is impossible to speculate about future apportionment levels, this analysis will calculate changes in each state's relative contribution to the HTF.

Calculating the Suits Index

The Suits index is essentially a Gini coefficient for the distribution of tax burden, instead of income, in a society (Suits 1977). The Gini coefficient, an indicator of income inequality, is calculated by first rank ordering the population according to family income and then comparing the share of income with the share of population at different points in the distribution. The Suits index is very similar but it compares instead the share of tax burden with the share of income. It measures how regressive a tax is based the relative share of accumulated tax payments to the accumulated income at any point in the distribution of household income in the population.[49] Traditionally, the Suits index has been calculated over income deciles for practical reasons (West 2005). However, it is more accurate to calculate the Suits index continuously over the total accumulation of taxes. It is also necessary to calculate the Suits index continuously over percentiles in order to calculate confidence intervals for significance testing (Anderson, Roy, and Shoemaker 2003).

The procedure for calculating the Suits index is fully described in the Technical Appendix but can be easily illustrated. Table 4.6 presents the accumulated fuel tax for each decile of accumulated income, for households rank ordered from the lowest earning to the highest earning, in the 2001 and 2009 NHTS. This table shows that the households earning the first ten percent of accumulated income contributed 22.4 percent of the total fuel tax revenue in 2008-09. The households that contributed the second ten percent of income, an accumulated twenty percent of the total income, contributed 15.7 percent of total tax revenue for an accumulated 38.1 percent of total revenue. Because of income inequality in the population, 37.1 percent of the population accounts for the first ten percent of income, in 2008-09, and 16.1 percent of the population account for the second ten percent of income; the lowest income 53.2 percent households account for 20 percent of income and 38.1 percent of the total fuel taxes. The highest income 16.9 percent of the population earn half of total income and bear 20.2 percent of the fuel tax. This is a regressive tax. For a progressive tax, the highest income households would pay a disproportionately greater share of the total tax relative to their income.

The Suits index facilitates an easy comparison between different taxes. A progressive tax has a positive value and a regressive tax has a negative value. A tax with a more negative Suits index is more regressive than a tax with a less negative Suits index. The Suits indices presented in Table 4.6 show that the combined state and federal gasoline taxes have a Suits index of -0.258 in the 2001 NHTS and a Suits index of -0.303 in the 2009 NHTS. This suggests that the gasoline tax may have become more regressive between 2001 and 2009. While interesting in itself, this example is provided to illustrate how to interpret the Suits index and is not intended to report a major research finding. There are some concerns about the income data in the NHTS and the assumptions made to estimate income for households earning more than $100,000 per year may be a leading factor

[49] "Accumulated" means to add one value to another. If the incomes of three households are 1, 2 and 3, then the accumulated income for the first household is the sum of the first household's income, 1, the accumulated income for the second household is the sum of the first and the second households' incomes, 1+2 = 3, and the accumulated income for the third household is the sum total of all the households' incomes, 6.

Table 4.6 Accumulated Gasoline Taxes for Income Tenths, 2001 & 2008

Income Decile	Accumulated Percentage of State & Federal Gasoline Taxes	
	2001 NHTS	2009 NHTS
0	0	0
1	18.9	22.4
2	33.6	38.1
3	47.1	51.4
4	58.8	63.4
5	69.3	73.9
6	78.3	79.8
7	85.6	84.9
8	90.5	90.2
9	95.2	95.1
10	100	100
Suits Index	-0.258	-0.303

underlying this finding.[50] These results should, however, motivate further research into whether the gasoline tax has recently become more regressive using other sources of income and expenditure data; from the consumer expenditure survey for example (Poterba 1991).

Calculating the Change in Consumer Surplus

Consumer surplus, as calculated in this metric, is the amount of utility enjoyed by a household from their consumption minus the pecuniary costs of that consumption. Households chose how much of each good to consume, subject to a budget constraint, given the prices of those goods and the unknown value that each household places on consuming each good. While the demand for travel is technically derived from the demand for other goods and to access markets (including labor markets), it is possible to model the household demand for travel like any other good where a trip will not be taken, or consumed, unless the expected marginal benefit of that trip exceeds the expected marginal cost. The model developed previously defines the slope of a demand curve for each household; this is the price elasticity.

Each household is, individually, a price taker because no household consumes enough fuel to influence the market price by a change in their demand. At the household level, an alternative tax policy will either increase or decrease the per-mile price of driving and the household will respond by reducing or increasing their annual demand according to their price elasticity. While it is not possible to calculate the total utility or consumer surplus of an individual household, it is possible to calculate their change in consumer surplus. Graphically, this is the area between the new and old prices underneath the demand curve. This is the green area in Figure 4.1.

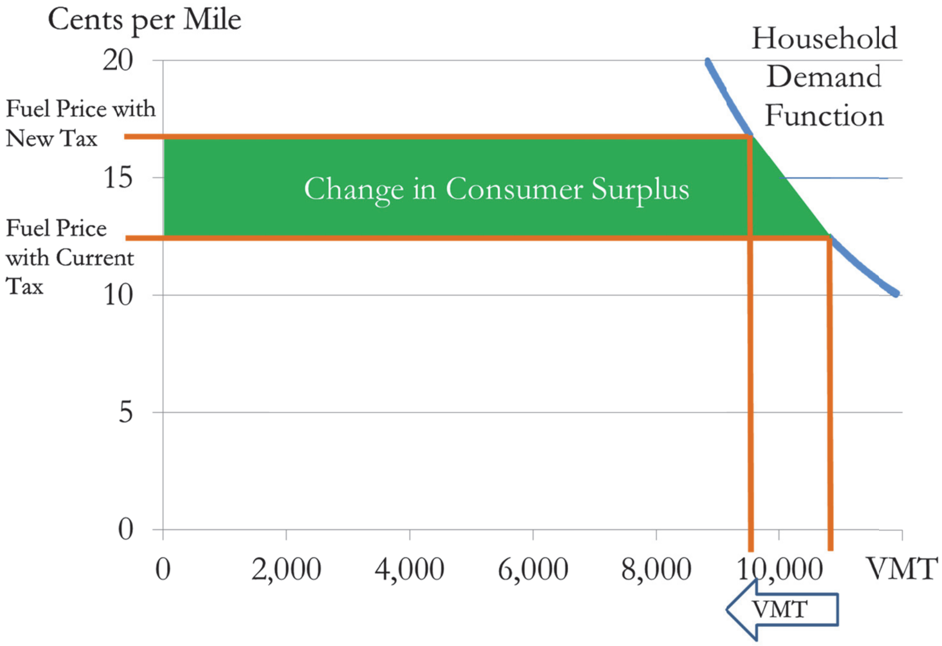
The change in consumer surplus is calculated by integrating the demand function specified previously in Equation 3.2 and solving the definite integral for each household using the parameters reported in Table 3.2 with each household's unique values for the income and vehicle characteristics between their initial and new prices. The full mathematical derivation for this calculation may be found in the Technical Appendix.

The flat-rate alternatives reduce the aggregate demand for VMT by about .2 percent. This will reduce the aggregate demand for gasoline by only .05 percent.[51] While the aggregate demand for

[50] The highest income category in the NHTS is "greater than or equal to $100,000." Approximately 10 percent of households fell into this category in the 2001 NHTS, increasing to approximately 18 percent in the 2009 NHTS.

gasoline in the United States could be large enough to affect the global price and supply of crude oil and gasoline, the short-run (3-6 month) price elasticity of gasoline is very inelastic because refineries cannot simply adjust more quickly (Alm, Sennoga, and Skidmore 2009). This means that a sudden increase in the tax rate could lead to a decrease in the price of fuel (exclusive of tax) and the oil companies would bear some of the incidence. However, in the long run, oil supplies and refining capacity are far more flexible and the incidence of the fuel tax falls heavily on consumers (Alm, Sennoga, and Skidmore 2009). However, given the very small changes in aggregate demand predicted for adopting most of the MBUF alternatives, and the fact that changes in tax policy are typically announced well before they go into effect, it is reasonable, as well as convenient, to assume that there is no supply response or change in the market price of gasoline from any of the alternatives. As previously discussed, the changes in consumer surplus will be underestimated because the supply and demand for vehicles and the supply for fuel are not explicitly modeled, the small magnitude of these inaccuracies are not expected to alter the conclusions. The 1 cent MBUF, tiered MBUF, and 17.7 cent MBUF alternatives, however, could have sufficiently increase the cost of driving to have a small, but more significant, impact on the aggregate demand for motor fuels. This change in demand could reduce somewhat the global market price of oil and the retail cost of refined petroleum products including gasoline and diesel motor fuels. Lower fuel prices would stimulate demand and partially offset the increase in the tax rate. These supply effects are not modeled but are discussed further, qualitatively, in the concluding chapter.

Figure 4.1 Change in Consumer Surplus



Note: The shape of the demand function in this example is given by a constant price elasticity of 0.43.

[51] This is lower than many might expect. The reason is that an equivalent flat rate MBUF will cause high efficiency vehicles to reduce VMT and low efficiency vehicles to *increase* VMT.

Calculating the Change in Welfare

The MBUF alternatives change net tax revenue, VMT and fuel consumption. These changes have an impact on the welfare of every person in society. The change in household welfare is calculated by adding the household's share of the change in tax revenue and externalities to their change in consumer surplus. Households owning no vehicles have no change in consumer surplus but are affected by changes in revenue and by changes in externalities.[52] Therefore, this change in welfare metric considers the equity implications for all households. This is important because prior research finds that whether an increase in the gasoline tax rate is regressive or progressive can depend entirely on how these changes in revenue and social welfare are returned to households (Bento et al. 2009). In particular, returning revenue to households in equal lump sums more than offsets the annual fuel and MBUF taxes in most low income households and, were revenues actually returned to households in this manner, the gasoline tax would be progressive. Despite the caution that must be exercised in allocating revenue and driving related externalities to households, and in interpreting findings based on this approach to calculating changes in welfare, this type of analysis is useful in more fully capturing the costs and benefits of a change in tax policy.

Calculating and Distributing the Change in Tax Revenue

The aggregate change in tax revenue is calculated by summing the change in annual household fuel and MBUF taxes over all households and then subtracting the estimated cost of administering the tax. These transportation revenues are used to maintain and improve roads and to subsidize public transportation. Gasoline taxes are used in some states to supplement the general fund or to generate revenue for other non-transportation related programs. Therefore, a change in total revenue affects all households to some degree. It is assumed that MBUF revenue would be used exactly as fuel tax revenue is used.

There are many possible ways to return this change in revenue to the households. Bento et al. (2009) use and contrast three approaches to return the increase in revenue from a higher fuel tax to households. They use the term "revenue recycling" to describe this process. "Flat" recycling distributes revenue in equal lump sums to each household. "Income-based" recycling distributes revenue proportionally to each household's contribution to aggregate income, where households with higher income receive a larger share of the revenue. "VMT-based" recycling distributes revenue proportionally to each household's contribution to aggregate VMT. In these approaches, households receive a rebate from the government (with an increase in income and rebound effect in their VMT as a result).

This approach, while simple, is unrealistic because the fuel tax and MBUF revenue is hypothecated for transportation expenditures. This study uses an alternative approach that is based on the use of the revenue. This alternative approach assumes that the net present life cycle value of the government's use of the transportation revenue is equal to the costs. The total revenue may then be treated as a positive externality to be enjoyed by each person without an income effect.

Two alternative methods are used to allocate the net change in revenue to each household:

- Equal distributions to each person, and
- Mixed equal and VMT-based distributions.

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52 Unless completely homebound, members of households that do not own vehicles travel as passengers in the vehicles of other households and use transit. Therefore, the welfare of these households is also affected by changes in transportation revenue and traffic congestion.

The first method divides total federal revenue by the population and then distributes an equal value per person in each household. State tax revenue is divided by the number of people in each state and distributed accordingly. It makes more sense to distribute the change in welfare per person instead of per household because larger households benefit more, or are harmed more, from better, or worse, roads and transit service. The second method is a mixed approach that allocates half of the change in revenue according to the first method, and the other half proportionally to household VMT. This second approach avoids the problem of allocating too large a benefit or cost to households that are relatively immobile and are less likely to benefit from, or be harmed by, the change in revenue that is hypothecated for transportation.[53]

Transitioning to an MBUF from the current system of fuel taxes would cause net revenues to decline because the cost of collecting, administering, and enforcing an MBUF will certainly be higher than the cost of the current system of fuel taxes. In fact, an important advantage of the gasoline tax over other forms of road pricing, including the MBUF, is that the gasoline tax is relatively inexpensive to collect. Motor fuel excise taxes are collected directly from the distributors, not the consumers. This vastly reduces the cost and complexity of collecting, administering, and enforcing the tax. There exists reliable data showing that the total cost of collecting and administering state and federal gasoline taxes is about 1 percent of revenue (Balducci et al. 2011).

Unfortunately, there are no comparable data on the costs of administering a light-duty vehicle MBUF given limited global experience with this type of charge. Existing evidence from tolled roads and comparable heavy truck VMT fee programs suggest that collection, administration, and enforcement costs will be significantly greater than 1 percent of revenue. The lack of any program of comparable scope and scale, combined with outstanding uncertainty regarding program details, reduces the calculation of an estimate to, at best, informed speculation. The best and most recent research, however, suggests that it would cost more than 20 percent of revenue to set up the system and more than 10 percent of revenue to annually administer, collect, and enforce an MBUF (Balducci et al. 2011, Table 34). In order to model the welfare effect of the MBUF alternatives, the costs of collecting, operating, and enforcing an equivalent flat-rate MBUF are assumed to be 10 percent of revenue. The collection cost is then held constant for other policy options with higher effective tax rates to capture the likely economies of scale. The total costs are unlikely to linearly increase with the tax rate. For example, the costs of collecting a tax would not be expected to double were the rate to double. Collection and administration cost of the gasoline tax are calculated at 1 percent of revenue (US FHWA 2009; Balducci et al. 2011, 89).

It is possible to analyze the MBUF alternatives using a rage of potential cost estimates, however that approach would have increased the number of alternatives to be analyzed unnecessarily. It is sufficient to note that these collection costs are at the low end of the range of the potential annual costs to operate and administer an MBUF system. For comparison, the average cost to operate toll facilities in North America is 34 percent of revenue (Balducci et al. 2011, 72). The ten percent of revenue assumption used to calculate the operating and administration of the MBUF policy options in this study are sufficiently large to illustrate how an MBUF, set at an equivalent rate to the current fuel tax, will result in a net decrease in revenue. A higher collection cost will further decrease net revenue.

[53] To allocate all of the change in revenue by VMT, or VMT-based recycling, would ignore the real social benefits of transportation spending and, more importantly perhaps, would be meaningless for analyzing the equity implications because each household would receive back in welfare exactly what they contributed in tax.

Distributing Social Costs and Benefits

Driving results in traffic congestion, accidents, and air pollution (Parry and Small 2005; Parry, Walls, and Harrington 2007; Ross Morrow et al. 2010; Zhang and Methipara 2011). Because MBUFs and higher fuel taxes reduce VMT and fuel consumption, travel-related externalities and greenhouse gas (GHG) emissions are also reduced. The marginal social cost of these travel related externalities, shown in Table 4.7, are central values from meta-analytical research by Parry and others (Parry and Small 2005; Parry, Walls, and Harrington 2007). A change in the amount of traffic congestion, accidents, and air pollution will affect the welfare of all households regardless of how much they drive.

The change in household welfare is calculated by first calculating the change in the value of each externality for each of the alternative policies. Those are calculated by multiplying the changes in VMT and gallons of fuel by the parameters listed in Table 4.7 and described in the following paragraphs. The dollar values of the aggregate changes of externalities are then divided by the total population and equal values are distributed to each household according the number of household members.

Local air pollution: Local air pollutants such as carbon monoxide, nitrogen oxide, various hydrocarbons (volatile organic compounds), and particulate matter are emitted by motor vehicles. These are regulated by federal "emissions standards, which must be met for each vehicle regardless of fuel economy, are defined in terms of grams per mile, rather than grams per gallon, and state-of-the-art technologies for meeting emissions standards are more durable over the vehicle life" (Parry, Walls, and Harrington 2007, 3). The central marginal external value of 2.6 cents per mile is a national average. Various studies cited by Parry, Walls, and Harrington (2007) provide a range from about 1.5 cents per mile to nearly 20 cents per mile.

Traffic congestion: Calculating a national average marginal external cost per mile of congestion is challenging because congestion costs vary not only by location but also the time of day. Parry and Small (2005) and Parry, Walls, and Harrington (2007) cite and interpret two FHWA studies that "weight marginal external costs for representative urban and rural roads, at different times of day, by the respective mileage shares" to calculate a national average value of 3.9 cents per mile. This is the best estimate available for this type of aggregated analysis (Parry and Small 2005). Given the NHTS data, which identifies households in MSAs larger than 1 million people, a more disaggregated analysis is possible and should be done for any study that is focused on the efficiency aspect of MBUFs.

Traffic accidents: Driving is one of the leading causes of death and injury in the United States. The private costs of driving are internalized in household decision making, but there are also marginal external costs of accidents which are not directly considered. The total annual social costs of traffic accidents are approximately $500 billion (Parry, Walls, and Harrington 2007, Table 2). These include lost productivity, travel delay and the external portions of medical costs and property damage, among other costs. The national average marginal external cost is 3.3 cents per mile.

Oil Dependency: The marginal external costs of oil dependency are based on the marginal effect of demand for oil on foreign oil producers' profits ("optimum tariff") and risks of macroeconomic disruption (Parry, Walls, and Harrington 2007). There are a wide range of estimates of the total marginal external cost of oil dependency with a central value of 13.4 cents per gallon. This value does not include Middle East military expenditures to secure oil supplies because those costs are not considered to be marginal costs (Parry, Walls, and Harrington 2007).

Risk of global warming: The marginal external cost of global warming per gallon of gasoline cited by Parry, Walls, and Harrington (2007), 7.8 cents per gallon, is based on estimates per ton of carbon ranging from $15 - $50 per ton. While there is a wide range of estimates, this value is too conservative given more recent research findings that often arrive at values above $50 per ton of carbon (Ackerman and Stanton 2011). The US Interagency Working Group on Social Cost of Carbon (2010) officially adopted the value of $81 per ton of carbon for federal regulatory analyses.[54] This is equivalent to 21.6 cents per gallon of gasoline.

These travel related externalities have not been included in prior analysis of the distributional implications of gasoline taxes or MBUFs. Parry, Walls, and Harrington (2007) speculate that doing so "would lower the net burden to households, and reverse its sign in many cases, given that marginal externality benefits from reducing congestion and accidents to the average road user appear to be well above the current fuel tax." Prior studies have considered the distribution of revenue in evaluating welfare changes in the analysis of distributional implications of fuel taxes (Bento et al. 2009), emissions charges (West 2005), and MBUFs (McMullen, Zhang, and Nakahara 2010). By including these travel-related externalities in the welfare calculation this dissertation will make an important contribution to the literature.

Table 4.7 Values for Travel-Related Externalities

Description of Externality	Economic Value
Distance Related Externalities	
Local air pollution damages	2.6 cents/mile
External congestion costs	3.9 cents/mile
External accident costs	3.3 cents/mile
Fuel Consumption Related Externalities	
GHG emissions, global warming	21.6 cents/gallon
Oil dependency	13.4 cents/gallon

Note: All dollar values have been adjusted from their published values to 2010 dollars.
Sources: Parry, Walls, and Harrington (2007, Table 3). The marginal social cost of global warming is adopted from US Interagency Working Group on Social Cost of Carbon (2010, 2).

[54] The official value is $21 per ton of CO2 in 2007 dollars. $81 per ton of carbon is $21 * 3.67, the multiplier for converting the molecular weight of CO2 to the molecular weight of carbon, and adjusted for inflation.

Sensitivity Analysis

EIA and ORNL made many assumptions in creating the estimated VMT, vehicle fuel economy, and fuel price variables. In addition, the model used in this analysis assumes that the price elasticity varies with income and vehicle stock attributes. A sensitivity analysis is conducted to understand whether the research findings reflect actual characteristics of the population or are being driven by these assumptions. A thorough sensitivity analysis improves confidence in the estimated results.

The analysis described above is repeated using five additional data sets that replace one or more variables with an alternative:

- Use the respondent's estimate of annual VMT in place of the ORNL estimate
- Use an alternative fuel price series, distributor reported gallons and revenue in place of the sample of retail stations (US EIA 2011c)
- Replace both annual VMT and fuel price
- Entirely drop vehicle types other than cars, van, SUVs and pickups.
- Use the unadjusted EPA fuel economy ratings instead of the estimated "in use" fuel efficiency variable created by EIA.

The VMT, fuel price, and MPG variables chosen to fit the model and conduct the baseline analysis were selected from among two or more alternative variables in the NHTS data because they were the more accurate or reliable estimates. As estimates, however, these variables have some bias and error. The alternative variables, used in the sensitivity analysis, were determined to be less accurate or reliable, as explained in more detail in data sections of the Technical Appendix. Consensus in the results across all of the alternative data sets allows for increased confidence in those results while disagreement may highlight concerns with the data and raise uncertainty about one or more of the findings.

In addition to running the full analysis with the alternative data sets, two additional sensitivity analyses are conducted as described previously. First, the changes in consumer surplus are estimated using two alternative constant estimates of price elasticity, -0.2 and -1, to examine how relaxing the assumption that the price elasticity is heterogeneous affects the results, if at all. Second, five alternative sets of thresholds and rates are used to examine for those alternatives affect the distributional implications of the tiered MBUF alternative.

PROJECTIONS

MBUFs are unlikely to be adopted on a large scale for many years and the future is uncertain. The analysis up to this point has comprehensively examined the distributional implications of the MBUF alternatives with current prices, incomes, and vehicle characteristics. In this stage of the study, household VMT is projected into future years 2015, 2020, 2025, and 2030.[55] This is done by using projections of average fuel economy, gasoline price, income and population from scenarios in the 2011 EIA *Annual Energy Outlook* (AEO) to adjust household variables in the model. The EIA AEO is an annual 30 year projection of US energy consumption based on current policy and historical consumption (US EIA 2011a). It provides an analysis of current energy policy and market trends. Transportation is a large share of energy consumption and the EIA makes

[55] VMT and other household variables are also projected for the year 2010 because the NHTS is for 2008-2009.

additional projections based on alternative assumptions about future oil costs, federal policy, and economic growth rates. These projections are used to develop scenarios for the NHTS data that can be used to examine how the distributional implications findings from the first stage of the research may change over time.

Project Fuel Economy, Price and Income over Future Years

The NHTS household data are projected using eight different scenarios based on the AEO "reference case" and six other scenarios:

- "Reference case" is the AEO's baseline projection which holds constant current state and federal energy policy and vehicle technology. It assumes central value forecasts of macroeconomic indicators such as income and price inflation.
- "High growth" projects a faster population growth and higher labor productivity. Consequently incomes also rise more rapidly in this scenario.
- "Low growth" is the opposite of the high growth scenario with slower income and labor productivity growth. Inflation is also higher in this scenario. These cases examine how alternative macroeconomic factors may affect the distributional implications of the MBUF alternatives.
- "High oil price" projects greater global demand for oil, pushing the real price to $200 per barrel by 2035. In this scenario, vehicle fuel economy improves more rapidly and the cost of fuel rises at a faster rate.
- "Low oil price" has the price per mile of travel falling and MPG improves slowly compared to the reference case. The oil price cases examine how both changes in price and vehicle fuel economy may affect the distributional implications of the MBUF alternatives
- "Extended policies" refer primarily to extending alternative energy policies that have a sunset date prior to 2035 and it expands several other policies. It is included because it assumes more stringent tailpipe emissions regulations and a 3-percent annual increase in light vehicle fuel economy standards, reaching 46 miles per gallon in 2025.
- "6% CAFE" implements a 6-percent annual increase in light vehicle fuel economy standards, reaching 59 miles per gallon in 2025.
- "Skew distribution" applies an adjustment factor to the reference case scenario to increase high fuel efficiency vehicles at a different rate than low fuel efficiency vehicles in order to examine how changing the distribution of vehicle fuel economy over time may affect the distributional implications.

Household fuel economy, fuel price, income, and the sampling weights are adjusted based on changes in the AEO scenarios. Projections are only calculated for the years 2010, 2015, 2020, 2025, and 2030. The projected variables from the AEO scenarios are replicated in Table 4.8.

Future household MPG, gasoline prices, tax rates, income and the sampling weights are calculated by applying a constant multiplier to the NHTS value for each scenario and year. The multiplier is calculated by dividing the projected value by the historical, 2009, value from the AEO projection tables. It is necessary to create this multiplier and apply it to estimates from the NHTS because of differences between the populations of the NHTS and the AEO. The NHTS measures only the population of households. The AEO makes projections for the entire economy, including

Table 4.8 Fuel Economy, Price, Population & Income Projections, 2010-2030

Case	Year	Fuel Economy (MPG)	Gasoline Price (2009 dollars/gallon)	Population (millions)	Income (2009 dollars)
Reference	**2009**	20.8	2.35	307.8	10,100
	2010	20.8	2.68	310.8	10,224
	2015	22.1	3.13	326.2	11,533
	2020	23.9	3.38	342.0	13,181
	2025	25.7	3.54	358.1	15,118
	2030	27.0	3.64	374.1	17,123
High Growth	**2015**	22.1	3.15	330.1	11,891
	2020	24.0	3.46	351.1	13,915
	2025	25.7	3.69	374.9	16,080
	2030	27.1	3.76	400.2	18,635
Low Growth	**2015**	22.1	3.11	324.3	11,235
	2020	23.8	3.32	335.1	12,469
	2025	25.6	3.49	343.7	14,171
	2030	26.9	3.52	351.5	15,704
High Oil Price	**2015**	22.2	4.27	326.2	11,434
	2020	24.3	4.85	342.0	13,100
	2025	26.3	5.12	358.1	15,097
	2030	27.9	5.26	374.1	17,089
Low Oil Price	**2015**	22.0	2.17	326.2	11,616
	2020	23.8	2.30	342.0	13,323
	2025	25.1	2.12	358.1	15,287
	2030	26.2	2.24	374.1	17,306
Extended Policies	**2015**	22.1	3.15	326.2	11,531
	2020	24.4	3.36	342.0	13,177
	2025	28.6	3.47	358.1	15,126
	2030	31.8	3.51	374.1	17,148
6% CAFE	**2015**	22.1	3.16	326.2	11,532
	2020	24.7	3.36	342.0	13,182
	2025	30.2	3.47	358.1	15,121
	2030	35.3	3.44	374.1	17,127

Notes: Fuel economy is the average "on-road" fuel economy for light duty vehicle stock. Gasoline price is the sales weighted average price for all grades and includes federal, state, and local taxes. Income is real disposable personal income.
Sources: "Light-Duty Vehicle Miles per Gallon by Technology Type," "Petroleum Product Prices," and "Macroeconomic Indicators" Tables for the reference case and the specified side cases (US EIA 2011a).

industry and public sector energy consumption. Another notable difference between the NHTS and the AEO is that income in the AEO is "disposable" income. This is less that total household income and is, therefore, not directly comparable to the NHTS estimates of total household income. If disposable income grows more rapidly than total income, this methodology may overestimate income in future years.

The projections based directly on the AEO projections increase fuel efficiencies at a constant rate across all households. One additional scenario was developed to force a change in the distribution of household fuel economy to examine how that could affect equity. It is likely that fuel economy of different types of vehicles will improve at varying rates over time. The method used to project household MPG in this "skew distribution" scenario first rank orders households by fuel efficiency and assumes that household preferences for fuel efficiency are constant relative to other households.[56] In this scenario, the least fuel efficient vehicles will not improve their fuel efficiency at all over time (assume that these are RVs which are not scrapped as they get older). Those households that do not value fuel efficiency today, are assumed to not value it is successive years, those who value it less than average continue to value fuel efficiency less than most and improve their fuel efficiency more slowly relative to most. Those households that value fuel efficiency more than most others will choose to continue to value fuel efficiency more and improve their fuel efficiency faster than average over time. And, lastly, those households which value fuel efficiency the most and have chosen to spend more money to be early adopters of hybrids, will continue to value fuel efficiency over time and replace their old vehicles with the most efficient vehicles. In order to model this scenario, the MPG of each household *i* in year *t*, is calculated by multiplying the inverse of the household's current MPG by the function in Equation 4.2:

$$\frac{gallons}{mile}_{i,t} = \frac{gallons}{mile}_{i,2009} \cdot \left(1 - \left(\frac{i}{I} \cdot \phi_t\right)\right) \tag{4.2}$$

ϕ_t is a constant multiplier whose value is selected so that the average fuel economy of the skewed distribution is approximately equal to the average MPG in the AEO reference case in year *t*. Table 4.9 presents the values of this multiplier for 2015, 2020, 2025, and 2030 and shows how the estimated average household MPG of the Skew Distribution equals the average MPG of the AEO Reference Case.

Table 4.9 Projected Average MPG Using Alternative Projection Methodology

t	ϕ^t	Average Estimated MPG	AEO Reference Case Average MPG
2015	0.20	22.1	22.1
2020	0.36	23.9	23.9
2025	0.49	25.7	25.7
2030	0.57	27.0	27.0

[56] Note that this assumption must be made for the other scenarios as well since all households improve their MPG at a constant rate.

5. THE EQUITY EFFECTS OF MILEAGE-BASED USER FEES

KEY FINDINGS

Equivalent flat-rate MBUFs have significant positive distributional implications for rural and for retired households. However, MBUFs are not consistently or strongly more or less regressive than motor fuel taxes. Hypotheses formed by reviewing summary statistics, bolstered by prior research findings, suggested that MBUFs are less regressive than the motor fuel tax. As will be shown, this no longer appears to be true. The change is likely due to an increased homogeneity in the distribution of the fuel economy of low and high income households. The positive distributional implications for retired households and households in rural areas are completely consistent with prior research. Nonetheless, state transportation officials and elected representatives continue to express concern about the rural equity of MBUFs. The findings in this study are consistent across all methods of examining the distributional implications of MBUFs and across all alternatives considered. While rural households do drive much further than urban households, the MBUF is clearly the fairest way of charging users for highway maintenance and construction.

Some of the opposition to MBUFs from rural areas may have more to do with concern about federal funding equity than about drivers' tax burdens. An original analysis of the jurisdictional funding equity implications of equivalent flat rate MBUFs suggests that a small number of states would likely have difficulty requesting continued levels of funding were MBUFs adopted. This may help to explain the continued opposition to MBUFs voiced by officials and members of Congress from rural areas in the face of the clear evidence that the welfare of a majority of rural households would be improved by replacing the fuel tax with a flat-rate MBUF.

By design, this study cannot draw strong conclusions about the economic efficiency of MBUFs. However, it is possible to make a general observation regarding the efficiency of MBUFs relative to fuel taxes. All of the MBUF policy options considered in this study are more effective than fuel taxes at reducing VMT and travel-related externalities. A detailed general equilibrium model would be able to confirm that the welfare gains from the reduced VMT more than offsets the higher travel costs. These results are compelling and consistent but the assumptions regarding the value of social externalities and the distribution of transportation revenue and other benefits largely drive these findings.

There are also several observations that should raise concerns among advocates of MBUFs. A flat-rate MBUF would increase the cost of driving high MPG vehicles while reducing the cost of driving low MPG vehicles. This works against other policies that create positive incentives for improved vehicle fuel efficiency and reduced petroleum consumption. An equivalent flat-rate MBUF appears to more efficiently incorporate the marginal social costs of driving into the price of travel than the fuel tax, but is probably less efficient than congestion pricing. Lastly, the cost of administering, collecting and enforcing an MBUF is sufficiently higher than fuel taxes that a merely equivalent rate would surely lead to lower net revenues available for transportation spending. All of these concerns can be addressed by alternative MBUF designs, and three in particular are examined in detail. However, it is not sufficiently clear that the MBUF options considered in this study are superior to an increased fuel tax rate in addressing these concerns.

FLAT-RATE MBUFS ARE NO MORE OR LESS REGRESSIVE THAN FUEL TAXES

Replacing federal fuel taxes with an equivalent flat-rate MBUF changes the unit of taxation from gallons of motor fuel to VMT. This change will either increase or decrease the cost of driving for every household. However, the magnitude of this change is small relative to the total cost of driving. Replacing the fuel tax with an equivalent flat rate MBUF changes the cost of driving by no more or less than 4 percent for 98.9 percent of households.[57] While the change in driving costs is small, drivers are responsive to changes in the marginal cost of driving and will increase or decrease their annual demand for VMT accordingly. The changes in tax policy therefore impact household tax burden through changes in annual taxes, VMT and the aggregate change in revenue and externalities.

In this section, these changes are analyzed to determine whether replacing fuel taxes with an equivalent flat-rate MBUF will improve or worsen household equity with respect to their ability to pay. Specifically, the average changes in fuel taxes, consumer surplus, and welfare, all distinct but related metrics of the burden of taxation, are disaggregated by income groups and compared to determine whether adopting a flat rate MBUF would result in a systematic change in household equity relative to the current system of fuel taxes.

Changes in metrics of tax burden are examined over two sets of income groups. The first set is "low," "middle," and "high" income households which are even thirds of the population sorted by income.[58] The second set is ten groups of even tenths of the population. Population thirds are used frequently because this is a convenient and intuitive level of aggregation. Population tenths are included in all tables in this section of the chapter, however, to facilitate a more disaggregated analysis.

Change in State and Federal Fuel and MBUF Taxes

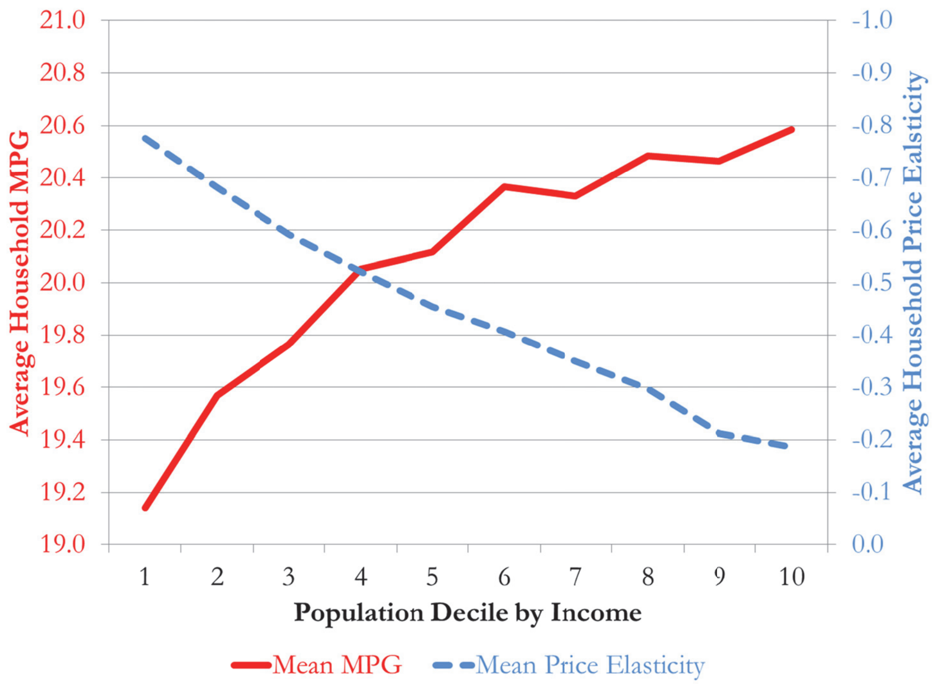
Percentage changes in the average household's annual federal fuel and MBUF taxes are presented in Table 5.1. This table shows that the percentage change is small and negative. The small magnitude of the change is unsurprising because the rate is equivalent. The change is not zero, however, because as noted previously in Chapter 4, the distribution of vehicle fuel economy is not normal. The distribution in vehicle fuel economy has a long right hand side tail. Consequently, while the average cost of driving decreases somewhat, the average VMT also decreases. This is unexpected because households with a decreased cost of driving increase VMT. The result reflects the positive relationship between VMT and MPG; households that drive more chose to own more fuel efficient vehicles and households that own more fuel efficient vehicles drive more because the marginal cost is lower.

There is also a positive relationship between income and VMT; households with higher incomes have a greater demand for travel than households with lower incomes because they have a larger budget for travel, a greater ability to pay, and generally make more trips related to work, entertainment, and shopping. These characteristics help to explain why higher-income households are less sensitive to changes in the cost of travel. Figure 5.1 illustrates the positive relationship between income and the price elasticity of demand for VMT. Figure 5.1 illustrates that MPG, also, is positively correlated with household income. This is consistent with prior research that found that

[57] The cost of driving for the most fuel efficient household increases by 14.3 percent, from 4.4 cents per mile to about 5 cents per mile. The average cost of driving is 14.0 cents per mile. And, to be clear, this is limited to fuel and taxes and excludes costs such as vehicle maintenance and depreciation, opportunity costs, and risks.

[58] Observant readers may note that there are only 18 categories of annual household income in the NHTS. After adjusting these for inflation using a monthly CPI, there are 252 income categories. To sort the distribution of households into even thirds and tenths without bias, each observation is assigned a very large random number that is used to rank order all the households within each of the 252 income categories.

Figure 5.1 Average Household MPG and Price Elasticity Over Income



low income households own older and less fuel efficient vehicles (West 2002, 2005; Bento et al. 2009). However, the result is biased, perhaps correctly, by the methodology used by EIA to adjust EPA fuel economy ratings for on-road conditions (US EIA 2011b).[59] In any event, all of these statistics indicate that a flat-rate MBUF should be less regressive than a fuel tax with an equivalent rate.

However, Table 5.1 and Table 5.2, which presents the results from a 50 percent increase in the federal fuel tax rate and its equivalent flat-rate MBUF, do not clearly indicate whether the flat-rate MBUF is more or less regressive than the fuel tax. The equivalent flat-rate MBUFs reduce the taxes of middle-income households more than other income groups. High income households continue to pay the most fuel taxes in absolute dollars, but the least as a percentage of their income. Of the low income households that realize a tax savings with the equivalent flat-rate MBUF alternative, only a third saves more than average.

Disaggregating the population into tenths does not clarify the results. The difference in the percentage change in the annual tax from one grouping to the next is greater in magnitude, in either direction, than the overall average. These inconclusive results suggest that a flat-rate MBUF would have no significant distributional implications relative to individual households' ability to pay.

[59] Households with a lower annual estimated VMT as assumed to make shorter tips, on average, than households with a higher VMT estimate. Therefore, the model used to adjust vehicle fuel economy assumes that a higher proportion of VMT in low-VMT households is made running the engine "cold" which is less efficient. Because VMT and income are strongly correlated, however, this model will, on average, calculate a lower on-road fuel economy estimate for a low-income household than a high-income household for the exact same vehicle. This creates a positive bias between income and the on-road fuel economy estimate.

Table 5.1 Percent Change in Average Annual Household VMT and Tax by Income Groups, Flat-Rate MBUF Equivalent to Current Fuel Tax Rate

	Current, 2008-09		Equivalent Flat-Rate MBUF, Federal Only			
	VMT (miles)	**Fuel Tax** (dollars/year)	**VMT** (miles)	**Percent Change**	**MBUF** (dollars/year)	**Percent Change**
Population Average	21,121	192.38	21,096	-0.12	192.16	-0.12
Population Third						
Low Income	12,188	110.87	12,163	-0.21	110.79	-0.07
Middle Income	21,655	197.53	21,625	-0.14	196.97	-0.28
High Income	29,517	268.73	29,500	-0.06	268.70	-0.01
Population Tenth						
1	8,315	75.97	8,299	-0.20	75.59	-0.50
2	11,358	101.96	11,328	-0.27	103.18	1.20
3	15,622	141.58	15,590	-0.20	142.00	0.30
4	18,014	164.72	17,983	-0.17	163.80	-0.56
5	19,339	178.24	19,315	-0.13	175.93	-1.30
6	23,331	211.98	23,302	-0.12	212.25	0.13
7	25,709	235.52	25,679	-0.11	233.90	-0.69
8	28,627	256.84	28,601	-0.09	260.51	1.43
9	30,140	275.08	30,125	-0.05	274.39	-0.25
10	30,745	281.84	30,733	-0.04	279.94	-0.68

Note: Includes households without vehicles.

Table 5.2 Percent Change in Average Annual Household VMT and Tax by Income Groups, Flat-Rate MBUF Equivalent to 50 Percent Increase in Fuel Tax Rate

	Federal Fuel Tax Rate Increased by 50 Percent		Increased Equivalent Flat-Rate MBUF			
	VMT (miles)	**Fuel Tax** (dollars/year)	**VMT** (miles)	**Percent Change**	**MBUF** (dollars/year)	**Percent Change**
Population Average	20,932	282.07	20,898	-0.16	281.62	-0.16
Population Third						
Low Income	11,998	161.49	11,963	-0.29	161.21	-0.18
Middle Income	21,442	289.68	21,401	-0.19	288.39	-0.44
High Income	29,354	395.02	29,329	-0.09	395.23	0.05
Population Tenth						
1	8,156	110.64	8,135	-0.25	110.63	-0.91
2	11,168	148.29	11,127	-0.37	149.94	1.11
3	15,403	207.10	15,361	-0.27	207.00	-0.05
4	17,796	241.00	17,752	-0.24	239.23	-0.73
5	19,138	260.91	19,104	-0.18	257.44	-1.33
6	23,112	310.50	23,072	-0.18	310.91	0.13
7	25,503	345.25	25,462	-0.16	343.11	-0.62
8	28,425	378.78	28,391	-0.12	382.59	1.00
9	29,991	407.32	29,972	-0.06	403.89	-0.84
10	30,619	410.83	30,598	-0.07	412.34	0.37

Note: Includes households without vehicles.

Suits Index

While it is possible to examine the change in annual taxes relative to income, this does not directly measure the regressiveness of the fuel tax and the MBUF alternative. A more precise measure of tax progressivity or regressivity is the Suits index (Suits, 1977). As described in Chapter 4, the Suits index measures how regressive a tax is based on accumulated tax payments across the entire population relative to accumulated income. This permits for a consistent comparison of different taxes. A tax with a negative value for the index is regressive, and if two taxes have a negative index, the one that is closer to zero is less regressive. The Suits index for the current gasoline tax is -0.3034 and the Suits index for the equivalent flat-rate MBUF is -0.3037, a difference of less than 0.0003. A complex method has been developed to conduct hypothesis tests on Suits indices (Anderson, Roy, and Shoemaker 2003), but these Suits indices are so nearly identical that it seems unnecessary do so here; they are clearly not significantly different from one another.

Change in Consumer Surplus

In Tables 5.1 and 5.2 above, the higher sensitivity of low income households to price changes is clearly illustrated. Low income households, on average, reduce their annual VMT by a higher percentage than other groups. Each of these additional or forsaken trips has a value to the household. The value of this travel should be accounted for in calculating the overall change in tax burden. The change in consumer surplus is one metric that captures the costs and benefits of changes in annual VMT that result from replacing the fuel tax with an MBUF.

The average change in household consumer surplus is presented in Table 5.3 for the population and for income groups. This table suggests that an MBUF might have a net positive impact for most households. More importantly for this study, however, is how this Table illustrates the distribution of the changes in consumer surplus by income. Replacing the federal fuel tax with an equivalent flat rate MBUF would increase the consumer surplus of middle income households by a larger amount than either low income or high income households.

There is not a clear distribution, however, for the alternative that replaces only the state fuel taxes with an equivalent MBUF. The difference between the results for the federal tax and the state taxes is likely the result of an interaction between the distribution of fuel efficiency, income, and variation in state tax rates. This will be revisited later in this chapter, in the section on the jurisdictional equity implications of MBUFs.

Increasing the federal fuel tax rate by 50 percent reduces consumer surplus for high income households by more than for lower income households because the higher income households are relatively insensitive to changes in prices and so their taxes increase by a greater amount. Lower income households have a more elastic response to changes in price and they reduce VMT to minimize the increase in their annual tax. In addition, the economic value of travel for lower income households is calculated to be somewhat smaller than for higher income households. The flat-rate MBUF equivalent to this higher fuel tax rate has distributional implications that are consistent with the lower rate MBUF.

Prior findings regarding the distributional implications of MBUFs are inconsistent and inconclusive. McMullen, Zhang, and Nakahara (2010) finds that the equivalent rate MBUF reduces the consumer surplus of low income households and increases the consumer surplus of high income households. This study is, however, limited to households in the state of Oregon. It is possible to replicate these findings by replacing state fuel taxes with an equivalent MBUF and limiting the results to Oregon households. The average change in consumer surplus for high income

Table 5.3 Change in the Consumer Surplus of Income Groups for Equivalent Flat-Rate MBUFs and 50 Percent Increase in Fuel Tax Rate

	Flat MBUF, Federal Only (dollars)	**Flat MBUF, State Only** (dollars)	**Flat MBUF, Federal & State** (dollars)	**Increased Fuel Tax (1)** (dollars)	**Increased Flat MBUF (2)** (dollars)
Population Average	2.21	2.71	5.06	-75.85	3.28
Population Third					
Low Income	1.82	1.95	3.91	-36.52	2.74
Middle Income	3.06	3.03	6.25	-76.46	4.79
High Income	1.75	3.15	5.01	-114.57	2.30
Population Tenth					
1	1.06	1.18	2.36	-23.14	1.87
2	1.17	1.34	2.64	-32.88	1.73
3	2.47	2.48	5.11	-49.26	4.09
4	3.14	3.03	6.32	-59.65	4.92
5	3.78	3.38	7.33	-69.45	5.51
6	2.47	2.92	5.54	-80.97	3.55
7	3.94	5.03	9.14	-93.23	5.55
8	-0.69	0.11	-0.45	-104.45	0.28
9	0.73	1.74	2.57	-122.09	3.48
10	4.05	5.90	10.04	-123.39	1.79

Notes: (1) This alternative increases the federal gasoline tax by 50 percent. (2) The changes in consumer surplus in this column are relative to the increased fuel tax.

households is $3.15, $3.06 for middle income households, and $1.82 for low income households. The results are less pronounced than the findings of (McMullen, Zhang, and Nakahara 2010) but these can be attributed to three major differences between the studies. McMullen, Zhang, and Nakahara (2010) uses only the 2001 NHTS, uses a similar but different model which estimated higher price elasticities, and calculates consumer surplus using a simplified algebraic method that approximates the change in consumer surplus instead of the definite integral of the demand function (which is more accurate).

Weatherford (2011) finds that the revenue neutral MBUF reduces the average consumer surplus of all income groups but is less regressive. In particular, the consumer surplus of low income households is reduced by less than the consumer surplus of middle and high income households. Further, the annual tax paid by low income households falls and the annual tax paid by high income households increases. As with McMullen, Zhang, and Nakahara (2010), Weatherford (2011) uses only the 2001 NHTS and specifies a model that estimates price elasticities that are elastic (greater than the absolute value of -1) for all income groups. These overestimated price elasticities appear to be the primary factor behind the different findings. Calculating the change in consumer surplus and tax for 2001-02, using the methodology in this study, finds that adopting flat rate MBUFs would be more, not less, regressive than the fuel tax. Weatherford (2011) acknowledges concern about the price elasticities and comments that "a different model that estimates or imposes a smaller price elasticity might arrive at different results." The effects of alternate price elasticity assumptions will be more thoroughly examined in the sensitivity analysis section of this chapter.

The results presented in Tables 5.1, 5.2 and 5.3 include households that do not own any vehicles because they are concentrated in low income households and this may affect the results. Twenty percent of low income households do not own a vehicle compared to 4 percent of middle income households and 2 percent of high income households. Households that do not own any vehicles obviously have no change in their tax or consumer surplus. These zero values regress the mean changes in annual tax and consumer surplus towards zero more strongly for low income groups than for the others. Table 5.4 compares the average changes in fuel and MBUF tax and consumer surplus over income groups including and excluding households without vehicles. The changes reported for all households, including those without vehicles, are consistent with the results presented in Table 5.1, for the change in federal tax, and Table 5.3, for the change in consumer surplus. However, the adjacent columns report average changes in tax and consumer surplus excluding households that do not own a vehicle. The difference in the estimated average change in taxes and consumer surplus from excluding those households without vehicles for low income households is remarkably different compared to the middle and high income groups. This is due to the fact that 20 percent of low income households do not own a vehicle.

Table 5.4 Comparison of Changes in Tax & Consumer Surplus Calculated of Income Groups Including and Excluding Households Without Vehicles

	Average Change in Federal Fuel and MBUF Tax (dollars)		**Average Change in Consumer Surplus** (dollars)		**Percent of Households Owning 0 Vehicles**
	Including 0 Vehicle Households	Excluding 0 Vehicle Households	Including 0 Vehicle Households	Excluding 0 Vehicle Households	
Low Income	-0.08	-0.10	1.81	2.29	20.5
Middle Income	-0.56	-0.58	3.06	3.18	3.7
High Income	-0.03	-0.03	1.75	1.78	1.6

Note: Changes are calculated for equivalent flat-rate MBUF, federal only, relative to current federal fuel tax rates.

Change in Household Welfare

Households that do not own vehicles are nonetheless affected by changes in tax revenue and VMT and bear some of the burden of fuel taxes. A reduction in tax revenue, for example, could lead to cuts in transit funding. Most members of households without vehicles travel on public roadways all the same, only in transit vehicles or as passengers in taxis or in automobiles owned by other households. Therefore these households may also be concerned with the condition of roads and delays due to traffic congestion. In addition, everyone is affected more or less equally by the externalities of driving such as air pollution and the social costs of accidents.[60] The changes in taxes alone and consumer surplus do not account for any of these externalities. The burden of taxation is not limited to impacts on budget and VMT. Further, as described in Chapter 4, the costs of taxation can be offset to some extent by various benefits. Calculating the change in welfare attempts to account for and distribute all of the public and private costs or benefits of the MBUF alternatives. As a practical matter, it is quite challenging to accurately account for all of the effects of a tax and many assumptions, stated in Chapter 4, must be made to reasonably estimate the change in welfare for each household. Despite the shortcomings of the welfare approach, it allows for a consistent comparison of the tax burden of alternative taxes across various groups.

The average change in welfare for income groups, from several MBUF options, are presented in Table 5.5 using two different approaches to the distribution (or "recycling") and

[60] As discussed in Chapter 4, the social costs of accidents differ from the private costs of accidents, the costs of which household consider in making travel decisions. These externalities include lost economic production and pecuniary costs of accidents borne by society (above those paid directly by the households and by insurance firms).

weighting of the changes in revenue. The first approach is to distribute it by dividing the net change in revenue by the population and distributing that to households by the number of people in each household. The average change in welfare using this method is identified in Table 5.5 as the "equal distribution." The second approach is to divide the net change in revenue into two halves. The first half is distributed equally to each person as with the first approach. The second half is distributed in proportion to each household's annual VMT. This approach, identified in Table 5.5 as the "mixed equal & VMT-based distribution," takes into account the fact that households that drive more also benefit more from an increase in revenue (or are hurt more by a decrease in revenue). The reasoning for this second approach is that much of the fuel tax revenue is directed towards the improvement of highway infrastructure and it is reasonable to assume that the same will continue to hold true for the proceeds of MBUFs. The net change in other driving related externalities are divided by the total population and distributed to households by the number of people in each household.

As noted previously, more low income households own zero vehicles than middle and high income households. This has been shown to be a key factor in determining the distributional implications of any transportation user fee. A regressive tax increase becomes progressive because the increase in revenue benefits those low income households that own zero vehicles (Bento et al. 2009). However, the concern is mitigated in part by distributing the externalities and revenue equally by person instead of by household. Low income households and, in general, households without any vehicles are also more likely to have fewer members. A household with five members has five times the weight as a 1 member household, for example. Given the fact that most HTF funding is expended on highway maintenance and construction it seems reasonable that more of the benefits would accrue to households with higher VMTs. Of the two, the second "mixed" approach would seem to present the more realistic distribution of the welfare change. Since the method affects the magnitude, but not the direction, of the distributional impacts, only the mixed methodology is reported in later tables.

The average changes in welfare for the equivalent MBUFs, as shown in Table 5.5, are all negative. The reason for this is the higher costs of collecting, administering, and enforcing an MBUF over a fuel tax with an equivalent rate. In order to collect equivalent net revenue, available for spending on transportation after subtracting the collection costs, a substantial rate increase on the order of ten percent would likely be necessary.[61] The results suggest, nonetheless, that a flat-rate MBUF would be more progressive than a fuel tax with an equivalent rate, but that there would be less revenue available for the public's benefit and, hence, a negative welfare change. The results also illustrate that a rate increase would be relatively progressive. This is unsurprising given the approaches to allocating the changes in externalities and revenue and the higher price elasticity of low income households. A higher rate reduces VMT and increases revenue; both of these factors have a positive effect on welfare that accrues to households regardless of whether or not they own a vehicle. Meanwhile, the negative change in consumer surplus for low income households is minimized, as previously shown in Table 5.5, due to their lower annual VMT and higher price elasticity.

While the average changes in welfare suggest that replacing the fuel tax with an MBUF could be less regressive, given the more ambiguous results of the change in consumer surplus, and the strong assumptions directing the distribution of the changes in revenue and in externalities, this is a cautious finding. The results are not strong enough to conclude that MBUFs would be significantly

[61] As discussed in Chapter 4, any discussion of collection and administration costs of MBUFs is highly speculative. The ten percent figure is intended to provide a reasonable but approximate order of magnitude. The actual increase needed would depend on actual collection, administration and enforcement costs as well as actual demand responses to the increased tax rate.

more or less regressive than motor fuel taxes. The distribution of fuel economy among the aggregated income groups is insufficiently heterogeneous to result in large distributional implications. However, MBUFs would create clear winners and losers.

Table 5.5 Average Change in Welfare of Income Groups From MBUF Options, Two Methods of Distributing Public Benefit of Tax Revenue

	Average Change in Welfare, Equal Distribution			**Average Change in Welfare, Mixed Equal & VMT-Based Distribution**		
	Flat MBUF, Federal (dollars)	**Increased Fuel Tax** (dollars)	**Increased Flat MBUF** (dollars)	**Flat MBUF, Federal** (dollars)	**Increased Fuel Tax** (dollars)	**Increased Flat MBUF** (dollars)
Population Average	-12.87	33.59	-11.12	-12.87	33.59	-11.12
Population Third						
Low Income	-11.19	57.88	-9.67	-8.67	45.17	-7.08
Middle Income	-11.73	30.90	-9.32	-12.12	32.79	-9.70
High Income	-15.70	11.99	-14.36	-17.84	22.80	-16.57
Population Tenth						
1	-11.79	70.09	-10.38	-7.76	49.80	-6.25
2	-11.31	57.66	-10.18	-8.76	44.76	-7.55
3	-11.20	49.92	-8.94	-9.72	42.44	-7.41
4	-10.81	41.58	-8.39	-10.17	38.29	-7.71
5	-10.41	33.58	-8.03	-10.19	32.38	-7.78
6	-12.53	27.91	-10.76	-13.49	32.70	-11.73
7	-11.99	22.28	-9.64	-13.41	29.42	-11.09
8	-17.74	19.20	-15.99	-19.73	29.22	-18.03
9	-16.86	5.47	-13.31	-19.17	17.22	-15.71
10	-14.09	8.20	-15.54	-16.34	19.37	-17.88

MBUF WINNERS AND LOSERS

In addition to analyzing the results by groups defined by their ability to pay, two other groups are analyzed in order to identify the potential winners and losers of a flat-rate MBUF. The first is household life cycle; households with children have significantly different travel demands than do households comprised of retired adults. And these types of households differ from various other kinds of households, a single young adult or a married couple without children, for example. The second is the type of community; households in rural areas have different travel needs than other types of communities. Three other types of communities, urban, "second city" and suburban, are examined. These are classified based on contextual residential density (McGuckin 2011). A suburban community is a less dense agglomeration of households adjacent to an urban area. A second city is a densely populated area that is not in or directly adjacent to a large metropolitan area. Urban, suburban, and city residents travel less, on average, and have better average vehicle fuel economy, than do the residents of rural areas.

Table 5.6 presents the average changes in fuel and MBUF tax, consumer surplus and welfare of these key groups for the equivalent flat-rate MBUF alternatives. The winners of this type of tax policy, those groups who would have a lower annual tax and an increase in consumer surplus, are retired households and rural households. The losers are non-rural households. Replacing any fuel tax with a flat-rate MBUF of an equivalent rate would increase the average annual tax of urban, second city, and suburban households.

Table 5.6 Average Changes in Federal Fuel and MBUF Taxes, Consumer Surplus, and Welfare for Key Groups

	Flat MBUF, Federal			Increased Flat MBUF		
	Average Change In:			Average Change In:		
	Annual Tax (dollars)	**Consumer Surplus** (dollars)	**Welfare** (dollars)	**Annual Tax** (dollars)	**Consumer Surplus** (dollars)	**Welfare** (dollars)
Population Average	-0.29	2.21	-12.87	-0.54	3.28	-11.12
Household Life Cycle						
Households with children	-0.63	2.32	-13.83	-1.00	3.39	-17.33
Retired households	-1.61	3.91	-6.27	-2.47	5.80	-3.87
Other households	0.95	0.92	-11.44	1.23	1.41	-10.53
Community Type						
Urban	4.55	-1.90	-13.83	6.42	-2.69	-13.89
Second City	3.46	-0.54	-14.41	4.91	-0.72	-13.89
Suburb	4.18	-1.60	-16.80	6.10	-2.47	-16.96
Rural	-6.82	7.56	-9.38	-10.09	11.17	-5.10

Note: The change in welfare is calculated using the mixed equal and VMT-based distribution approach.

The average annual tax for retired households is reduced by $1.61 relative to the current fuel tax. Were the federal fuel tax first increased by 50 percent, adopting an equivalent flat-rate MBUF policy would save retired households and average of $2.49 annually. The taxes of households with children are also reduced, on average, but not by nearly as much. Other types of households would pay more in taxes. The changes in consumer surplus are consistent with these findings. Retired households have larger gains relative to households with children and other households. These findings are also consistent with prior research by Weatherford (2011). Despite the previously identified negative change in welfare, due to the higher collection costs of MBUFs, the average changes in welfare are consistent with the other two metrics for these groups. Retired households have a smaller loss in welfare than do other households. One difference, however, is that the average change in welfare is far more negative for households with children. This is because households with children both have more household members and high VMT on average than other households. Were the net change in revenue positive, households with children would disproportionately benefit from the increase in revenue.

The average annual tax for households located in rural areas is reduced by $6.82 relative to the current fuel tax. Were the federal fuel tax first increased by 50 percent, adopting an equivalent flat-rate MBUF policy would save retired households and average of $10.15 annually. The taxes of households located in urban, second city, and suburban areas are all increased by, respectively, $4.55, $3.46, and $4.18 relative to the current fuel tax. The changes in consumer surplus are consistent with the change in tax, with non-rural households losing a small amount of consumer surplus and rural households enjoying a relatively large increase in consumer surplus. This difference in magnitude is attributable to both the higher demand for VMT in rural areas and the lower average MPG. Suburban areas have a far higher VMT than urban areas, 21,061 to 13,860, but not a significantly different MPG and so it is curious that their change in consumer surplus is not larger than it is. These findings are consistent with prior research by McMullen, Zhang, and Nakahara (2010) and Weatherford (2011) who also find that flat-rate MBUFs reduce the annual tax and increase the consumer surplus of rural households while having the opposite impact on urban households.[62]

[62] Suburban households were not specifically examined in prior research as simpler Census definitions of urban and rural were used.

While an equivalent, flat-rate MBUF would be especially positive for rural households, it is essential to understand that the equivalent rate would reduce net revenue. The change in welfare, while negative, is calculated to be smaller for rural households than for non-rural households. This finding suggests that the increase in the consumer surplus in rural areas more than offsets the loss in revenue. While unsurprising, given prior research findings and statistical facts about the lower fuel efficiency of vehicles owned by rural households, this result is significant because the most vocal opponents of MBUFs are from rural areas (Lummis 2011; McCaskill 2011). Rural opposition to MBUFs is not entirely meritless. The next section of this chapter presents results of alternative rate structures and those results illustrate how any increase in the tax rate increases the tax burden of rural households by more than urban households. An increase in burden that is proportional to mileage, to be sure, but an increase nonetheless.

The various factors comprising the net change in household welfare are variably impacted by VMT fees for different groups. Table 5.7 disaggregates the average change in welfare into the change in consumer surplus, redistributed revenue, and externalities for equivalent flat-rate MBUFs. This clarifies how low income and retired households benefit from the equal distribution because their VMT is relatively smaller. This effect also offsets some of the large loss of consumer surplus in urban areas. Households with children receive larger benefits from the equal distribution of revenue also because they are larger. Households with children also benefit from the mixed method because their annual VMT is higher as well. The consumer surplus gain to rural households is offset by the larger loss in revenue for the equivalent rate MBUFs with the mixed method. An increased tax rate, as is illustrated in the following section, also benefits rural households because of their higher annual VMT.

INCREASED RATES AND ALTERNATIVE RATE STRUCTURES

Overview of Alternative MBUF Rate Structures

Replacing the fuel tax with an equivalent flat-rate MBUF raises several concerns. With an equivalent rate, the MBUF will not increase revenue, which many observers believe is necessary. Further, any MBUF will probably reduce net revenues because the new tax will be more costly to administer, collect, and enforce. In addition, a flat rate MBUF increases the cost of driving high MPG vehicles and decreases the cost of driving low MPG vehicles. This works against other state and federal policies to encourage better energy efficiency. Lastly, while the flat-rate MBUF begins to more efficiently incorporate the marginal external costs of driving, the tax rate is lower than the total marginal external cost of driving. It is also less efficient than fuel or carbon taxes to price the social costs of CO2 emissions. An equivalent flat-rate MBUF is clearly not the only possible rate structure. Indeed, many alternatives are possible and three additional alternatives are analyzed in this study. These three alternatives address all of the above concerns regarding flat rate MBUFs in different ways.

The first alternative levies a flat-rate MBUF of 1 cent in addition to current fuel taxes. This alternative increases revenue more efficiently, sustainably and, arguably, more equitably than would an equivalent increase in the gasoline tax. However, it leaves in place the existing incentives for vehicle fuel efficiency while increasing the cost of driving for all households. The higher cost of driving reduces VMT and, while this policy reduces the weighted average fuel efficiency, it still reduces fuel consumption and GHG emissions by 2 percent. The changes in fuel consumption, CO2 emissions and average MPG are presented in Table 5.8

Table 5.7 Components of Welfare Change for Key Groups

	Flat MBUF, Federal				Increased Flat MBUF			
	Average Change in:				Average Change in:			
	Consumer Surplus (dollars)	**Revenue, Equal** (dollars)	**Revenue, Mixed** (dollars)	**Externalities** (dollars)	**Consumer Surplus** (dollars)	**Revenue, Equal** (dollars)	**Revenue, Mixed** (dollars)	**Externalities** (dollars)
Household Life Cycle								
Households with children	2.32	-28.18	-25.85	4.00	3.39	-28.58	-26.24	5.51
Retired households	3.91	-12.39	-11.93	1.76	5.80	-12.57	-12.09	2.42
Other households	0.92	-11.57	-14.01	1.64	1.41	-11.74	-14.20	2.26
Community Type								
Urban	-1.90	-17.17	-14.36	2.43	-2.68	-17.44	-14.57	3.35
Second City	-0.54	-17.04	-16.29	2.42	-0.72	-17.28	-16.51	3.34
Suburb	-1.60	-17.95	-17.75	2.55	-2.45	-18.21	-18.01	3.51
Rural	7.56	-17.85	-19.47	2.53	11.17	-18.02	-19.75	3.48

Table 5.8 Changes in Fuel Consumption, Carbon Dioxide Emissions, & MPG

	Change in Fuel Consumption (million gallons)	**Change in CO2 Emissions** (million tons of CO2)	**Percent Change in MPG (1)** (percent)
Equivalent Flat Rate MBUFs			
Flat MBUF, federal only	-35	-0.3	-0.09
Increased flat MBUF (2)	-45	-0.4	-0.12
Alternative MBUF Designs			
1 Cent MBUF	-2,310	-20.3	-0.12
Tiered MBUF	-1,470	-12.9	0.22
17.7 Cent MBUF	-21,900	-193.0	-0.95
Increased Fuel Tax Rate			
50 percent increase	-1,020	-9.0	-0.01

Note: (1) MPG calculated by dividing total household miles by total household gallons. (2)Changes calculated with respect to the increased fuel tax rate.

The second alternative replaces the fuel tax with a two-tiered MBUF. The rate levied depends on the vehicle's EPA fuel economy rating. As introduced in Chapter 4, vehicles with a fuel economy rating above a certain threshold, set at the median EPA fuel economy rating of 25.1 MPG, pay a low rate per mile while vehicles below that threshold pay a high rate per mile. As modeled here, the rates are intentionally extreme so that the least efficient vehicles do not have an incentive to increase VMT and the most efficient vehicles are not subjected to a tax increase. The high rate is set to 2.9 cents per mile, which is the highest federal tax per mile by any household, and the low rate is set to 0.3 cents per mile which is the least federal tax paid per mile by any household. The rates are set at the extrema so that the least efficient vehicle does not get a tax "cut" and the most efficient vehicle does not get a tax "increase." This is an unrealistic design intended to compare the distributional implications with the other alternatives. Table 5.8 illustrates how this alternative reduces VMT, improves MPG (prior to changes in household vehicle and mode choice), and reduces CO2 emissions.

The third alternative replaces all fuel taxes with a very high 17.7 cent per mile MBUF that is intended to fully price the marginal social cost of driving and, additionally, to efficiently increase general fund revenue with the optimal Ramsey tax for a VMT fee.[63] This alternative is intended to examine the potential equity implications of a mileage based increase in the cost of driving equivalent to an approximately $3.50 increase in the retail price of gasoline. While this would be approximately equivalent to doubling the cost of driving, it should be noted that $7 - $8 dollars a gallon is closer to the retail price of gasoline in many other Organization for Economic Co-operation and Development (OECD) countries than is the current price in the US. While the 17.7 cent per mile MBUF is a large increase and is not a credible policy option, such a tax rate is nonetheless within the range of practice globally. Moreover, the percentage increase is actually within the nation's recent experience with the real price of gasoline. A complete distributional analysis that explicitly considers a Ramsey tax option would need to model the effects of reducing or eliminating other, less efficient taxes such as the general sales tax. This alternative would reduce VMT by nearly 20 percent and, consequently, reduce fuel consumption and CO2 emissions substantially.

Distributional Implications of Higher Tax Rates

The increased tax rates discussed previously in this chapter and all three of these alternative MBUF rate structures increase the average tax rate per mile from the current fuel tax rate. Therefore, all of these alternatives result in lower average VMT, higher average taxes, and a negative change in consumer surplus for the population, on average, and all key groups. All of the higher tax rates, as discussed previously, reduce the tax burdens of low income households by a greater percentage than middle and high income households because of their higher price elasticity.

The progressive effect of increasing the tax rate is reflected in Table 5.16 which presents the Suits indices for all of the eight alternatives in the first column. The Suits indices for the 50 percent increased federal fuel tax and its equivalent flat-rate MBUF, -0.301, are slightly less negative than the Suits indices for the current fuel tax rate and it's equivalent flat-rate MBUF, -0.304. The three alternative MBUF rate structures are even less negative indicating that they are less regressive. The only alternative with a Suits index clearly less regressive than -0.30 is the 17.7 cent MBUF, which has a Suits index of -0.25.

[63] This rate was calculated in another study (Parry and Small 2005) and its use here is not intended to examine whether it is more or less efficient although that might be interesting to examine given the new data from the 2009 NHTS.

The finding that increasing the rate of the transportation tax, regardless of whether it is a fuel tax or an MBUF, reduces the regressivity of the tax is reinforced in Table 5.9. Increasing the tax rate increases the annual tax paid by low income households by a smaller percentage than middle and high income households. Table 5.10 further shows that all the alternative MBUF designs reduce the consumer surplus of low income households by less than middle and high income households. Likewise, the alternatives increase the welfare of low income households by a larger amount that household with higher incomes. It should be clearly stated, however, that while a higher tax rate is less regressive, this is due entirely to the higher price elasticity of low income households. Table 5.9 shows that as the cost of driving rises, low income households will reduce VMT by a larger percentage than middle and high income households. While a higher fuel tax or MBUF rate is less regressive than a low rate, it can be argued that a high fuel tax or MBUF rate is not necessarily "fairer" in considering the relative mobility of households.

Distributional Implications of Alternative MBUF Rate Structures

The distributional implications of the alternative where a 1 cent MBUF is added to the existing fuel taxes fall in between a fuel tax and an MBUF as expected. The relatively positive impacts for rural and retired households previously identified are still present, as shown in Tables 5.9 and 5.10, but to a lesser extent. And the relatively negative impacts on urban households are similarly less dramatic. This finding suggests that adding an MBUF as a tax increase, instead of replacing the fuel tax with an MBUF, would allow a more gradual transition to an MBUF system from an equity standpoint in addition to addressing the concerns about fuel efficiency and environmental incentives.

The distributional implications of the tiered-rate MBUF are quite different from the flat rate MBUF alternatives. The tiered rate MBUF seems to negatively impact households with children more than in other alternatives but, as will be shown in the following section, this seems to be driven by the specific details of the modeled rate structure. Retired households initially are relatively positively impacted but, as with households with children, this finding is driven by small differences in the distribution in household fuel efficiency. Small changes in the rate threshold have dramatic effects on the results. The distributional implications of the tiered rate MBUF for rural and urban households are more consistent with expectations with the opposite effect of a flat rate MBUF. An MPG-based tiered rate MBUF, especially one with a large difference in the high and low rates, would favor urban households over rural households. The particular rate structure that was modeled doesn't reduce the average urban tax burden, but is increases it by less than rural households. A tiered rate MBUF is estimated to increase the welfare of urban households and reduce the welfare of rural households. The tiered-rate MBUF was designed to have the opposite effect from a flat rate MBUF so these findings are expected.

Table 5.9 Percent Change in VMT and Taxes for Alternative MBUF Designs

	Increase Fuel Tax Rates by 50 Percent				Alternative MBUF Designs					
	Increased Fuel Tax		Increased Flat MBUF		1 Cent MBUF		Tiered MBUF		17.7 Cent MBUF	
	Change in:		Change in:		Change in:		Change in:		Change in:	
	VMT (percent)	Tax (percent)	VMT (percent)	Tax (percent)	VMT (percent)	Tax (percent)	VMT (percent)	Tax (percent)	VMT (percent)	Tax (percent)
Population Average	-0.9	21.4	-1.1	21.3	-2.1	48.5	-1.0	37.7	-19.7	632.8
Population Thirds										
Low Income	-1.6	20.6	-1.8	20.5	-3.7	46.3	-1.5	31.3	-32.3	518.8
Middle Income	-1.0	21.3	-1.2	21.0	-2.3	47.9	-1.1	36.0	-21.8	609.6
High Income	-0.6	21.8	-0.6	21.9	-1.3	49.8	-0.8	41.6	-12.9	697.2
Household Life Cycle										
Household with children	-0.8	21.6	-0.9	21.5	-1.8	49.0	-1.2	42.1	-16.9	658.9
Retired household	-1.1	21.2	-1.2	20.3	-2.5	47.3	-1.0	32.6	-23.3	592.2
Other households	-1.0	21.2	-1.2	21.6	-2.4	48.3	-0.9	34.5	-21.5	618.9
Community Type										
Urban	-1.1	21.7	-1.4	24.2	-2.6	50.9	-0.8	30.5	-24.1	637.0
Second City	-1.0	21.4	-1.3	22.8	-2.4	49.5	-1.0	34.1	-22.0	632.3
Suburb	-0.9	21.6	-1.1	23.1	-2.0	50.2	-0.8	35.1	-19.1	661.2
Rural	-0.9	21.3	-0.9	19.3	-1.9	46.8	-1.2	41.6	-18.1	618.7

Note: All changes in consumer surplus and welfare are calculated with respect to the current fuel tax rate to better compare the alternative MBUF designs with the increased fuel tax rate and it's equivalent flat-rate MBUF.

Table 5.10 Change in Consumer Surplus and Welfare for Alternative MBUF Designs

	Increase Fuel Tax Rates by 50 Percent				Alternative MBUF Designs					
	Increased Fuel Tax		Increased Flat MBUF		1 Cent MBUF		Tiered MBUF		17.7 Cent MBUF	
	Change in:		Change in:		Change in:		Change in:		Change in:	
	Consumer Surplus (dollars)	Welfare (dollars)	Consumer Surplus (dollars)	Welfare (dollars)	Consumer Surplus (dollars)	Welfare (dollars)	Consumer Surplus (dollars)	Welfare (dollars)	Consumer Surplus (dollars)	Welfare (dollars)
Population Average	-77.85	33.59	-72.58	22.47	-170.46	59.68	-127.65	35.88	-2,422.71	843.48
Population Thirds										
Low Income	-36.52	45.17	-33.79	38.06	-80.84	91.24	-46.37	74.87	-1,055.27	1,237.62
Middle Income	-76.46	32.79	-71.67	23.08	-170.24	59.29	-124.94	38.46	-2,377.50	851.67
High Income	-114.57	22.80	-112.27	6.28	-260.30	28.52	-211.63	-5.69	-3,835.07	441.23
Household Life Cycle										
Household with children	-106.12	57.74	-102.73	40.45	-239.57	105.96	-200.33	43.47	-3,456.37	1,473.27
Retired household	-44.20	30.60	-38.41	26.73	-96.29	61.02	-61.75	49.96	-1,331.92	856.39
Other households	-70.46	13.70	-69.06	3.14	-159.48	16.64	-107.64	19.12	-2,245.41	261.60
Community Type										
Urban	-45.42	47.38	-48.10	33.44	-105.27	90.49	-58.53	79.48	-1,471.99	1216.92
Second City	-62.46	39.95	-63.17	26.02	-142.71	72.70	-90.57	62.25	-2,008.61	1004.51
Suburb	-75.80	34.91	-78.25	17.93	-174.80	58.06	-117.03	48.49	-2,499.30	809.79
Rural	-95.29	23.86	-84.12	18.81	-208.97	41.26	-181.18	-2.82	-2,980.40	627.34

Note: All changes in consumer surplus and welfare are calculated with respect to the current fuel tax rate to better compare the alternative MBUF designs with the increased fuel tax rate and it's equivalent flat-rate MBUF.

Alternative Tiered MBUF Rate Structures

The tiered-rate alternative uses extreme tax rates that could be considered unrealistic. A distributional analysis is performed on 5 variations of this tiered MBUF option to examine how sensitive the results are to certain rate and threshold design characteristics. Table 5.11 shows how increasing the threshold causes the average annual tax to increase and VMT to fall as more vehicles get charged the high rate. Consistent with the results presented above, the lower total VMT and higher net revenue lead to larger aggregate declines in consumer surplus and increases in welfare. Lowering the rates with the 25.1 MPG threshold reduces the total tax burden and this increases consumer surplus and reduces welfare primarily due to less revenue (after the higher collection costs have been subtracted) for the public benefit.

Table 5.12 disaggregates the results by key groups and calculates the percentage change in consumer surplus relative to the primary tiered MBUF rate structure. As noted previously, the tiered MBUF is less regressive than the current fuel tax. These results show that reducing the high tax rate may further reduce the burden of this alternative on low income households. However, the effect is small and, in absolute terms, middle and high income households have a larger increase in consumer surplus. Increasing the threshold clearly increases the regressivity of the tiered MBUF.

Unlike the flat-rate MBUF, the tiered MBUF significantly reduces the consumer surplus of households located in rural areas. Reducing the high tax rate improves the consumer surplus of rural households, but not by nearly as much as urban households. However, increasing the threshold harms urban households far more than it does rural households. The reason for this is that rural households own fewer vehicles above the median fuel economy and therefore fewer households in rural areas have a change in their tax status. In other words, most of the households were already paying the high rate and so relatively few households would be further harmed by increasing the threshold.

The results illustrate how the specific design characteristics of the tiered MBUF, specifically where the threshold is set relative to the distribution of household fuel economy, may have strong equity implications for some groups. In the initial tiered-rate MBUF, households with children have a relatively large negative change in consumer surplus, but the percentage change in consumer surplus is relatively modest, compared to other groups, as the threshold is raised. In contrast, the initial average change in consumer surplus is relatively small for retired households, but as the threshold is raised their loss of consumer surplus increases by 400 percent. The reason for this difference is the distribution of household vehicles around the median EPA fuel economy ratings for these two groups.[64] The majority of households with children own vehicles with an EPA fuel economy rating that is less than the population median so that, as the threshold rises, the consumer surplus of fewer households is reduced. Many retired households, on the other hand, appear to own vehicles with an EPA fuel economy rating between the initial threshold of 25.1 MPG and the higher 27.6 MPG threshold. When the threshold is raised, all of these households have a large reduction in their consumer surplus.

These results illustrate that the rate structure of a tiered MBUF can have strong distributional implications. A rate structure with more tiers might be desirable. For example, large trucks could be charged a very high rate, pickup trucks, SUVs, large cars could be charged a lower rate, but higher than an incentive rate for the most fuel efficient vehicles. It is important to keep in mind that too many tiers increases the complexity of the system and reduces some of the benefits

[64] While the analysis uses estimates of "on-road" fuel efficiency to calculate fuel consumption, the tiered rate MBUF alternative is modeled with a threshold set at the unadjusted EPA fuel economy rating.

of adopting MBUFs. Specifically, the revenue sustainability goal of MBUFs is weakened by a multi-tiered or continuous MPG-based rate structure.

Table 5.11 Summary of Alternative Tiered-MBUF Rate Structures

Tiered MBUF Alternative	VMT (billion miles)	Federal Tax (billion $)	Suits Index	Change in: Consumer Surplus (billion $)	Change in: Welfare (billion $)
Threshold=25.1 MPG, high=2.9, low=0.3 (1)	2,360	39.60	-0.288	-14.40	4.06
Threshold=25.1 MPG, high=1.5, low=0.5	2,390	20.80	-0.300	1.10	-2.16
Threshold=27.6 MPG, high=2.9, low=0.3	2,340	50.00	-0.293	-23.30	8.32
Threshold=27.6 MPG, high=1.5, low=0.5	2,390	23.70	-0.302	-1.27	-0.92
Threshold=31.4 MPG, high=2.9, low=0.3	2,310	58.90	-0.291	-31.10	9.26
Threshold=31.4 MPG, high=1.5, low=0.5	2,380	26.10	-0.301	-3.36	0.11

Note: (1) This is the rate structure of the initial tiered MBUF used previously in this Chapter.

Table 5.12 Change in Average Group Consumer Surplus for Alternative Tiered-MBUF Rate Structures

	Change in Consumer Surplus for Initial Tiered MBUF (dollars)	Percentage Change in the Change in Consumer Surplus: 25.1 MPG Threshold High=1.5 Low=0.5 (percent)	27.6 MPG Threshold High=2.9 Low=0.3 (percent)	27.6 MPG Threshold High=1.5 Low=0.5 (percent)	31.4 MPG Threshold High=2.9 Low=0.3 (percent)	31.4 MPG Threshold High=1.5 Low=0.5 (percent)
Population Average	-127.65	108	-61	91	-116	77
Population Thirds						
Low Income	-46.37	119	-89	95	-162	75
Middle Income	-124.94	109	-63	92	-118	77
High Income	-211.63	104	-54	90	-104	77
Household Life Cycle						
Household with children	-200.33	106	9	96	-25	86
Retired household	-61.75	112	-394	67	-538	28
Other households	-107.64	109	-5	97	-44	86
Community Type						
Urban	-58.53	115	-83	93	-166	71
Second City	-90.57	112	-76	92	-149	72
Suburb	-117.03	109	-73	90	-139	72
Rural	-181.18	105	-51	91	-92	80

JURISDICTIONAL OR POLITICAL EQUITY

The opposition to MBUFs from rural areas and representatives from rural states may seem curious to analysts who understand that rural fuel economy is far lower on average than the fuel economy of households in non-rural areas. But these concerns may be based on uncertainty about how the change in tax burden might affect their share of federal-aid highway funding. One likely outcome of an MBUF is greater transparency regarding where travel is actually occurring. Many rural areas are donee states; they receive a higher proportion of federal transportation aid than they contribute. This is widely considered to be good policy because the major highways in these states are critical infrastructure that contributes to the mobility of people and freight across the nation. However, the total fuel consumption in these states generates insufficient fuel tax revenue to fully pay the costs of maintaining all of the roads in those states and, therefore, a federal subsidy is necessary to ensure the interstate routes are not neglected (US GAO 2010; Kirk 2004). The political outcomes regarding transportation funding equity under an MBUF cannot reasonably be speculated upon. However, Table 5.14, which presents the total percentage change in the taxes of the households in each state for the flat-rate MBUF alternatives, illustrates why some rural states may be concerned.

Eleven states are predicted to reduce their federal transportation tax contributions to the HTF by more than 5 percent. This reflects a relatively large decrease in the taxes paid by households in those states. However, from the perspective of a state transportation official or the states' Congressional delegations, this distinction might present a political liability by weakening the negotiating positions of donor states to request more, and of donee states to avoid a loss of, Federal-aid transportation funds. At the same time, 6 states are predicted to increase their federal transportation tax contributions to the HTF by more than 5 percent. While this reflects a higher tax burden on households in these states, the increase in their share would very likely result in the receipt of additional federal funds for those donor states because there is a minimum funding guarantee (US GAO 2010). A relatively large increase in contributions also strengthens the position of those donee states to maintain, or perhaps even increase, their levels of federal aid. Donee states are highlighted in Table 5.14. Table 5.13 divides the states into four groups based on whether they would contribute more or less tax revenue to the HTF were an equivalent flat rate MBUF to replace the federal fuel tax and their donor or donee status as listed in Table 4.5. Those 16 states with an increase or a decrease in total federal transportation tax of greater than 5 percent are in boldface.

Table 5.13 States by Donor/Donee Status and Change in Federal Tax Collected

Donor States	Donee States
Increase in Tax Collected	**Increase in Tax Collected**
California, Florida, **Illinois**, Indiana, Kentucky, Maine, **Maryland**, Massachusetts, Minnesota, New Jersey, Ohio, and Virginia. (12 states)	**Connecticut**, Delaware, Washington D.C., Hawaii, **New Hampshire**, New York, Oregon, Pennsylvania, **Rhode Island**, **Vermont**, and West Virginia. (11 states)
Decrease in Tax Collected	**Decrease in Tax Collected**
Arizona, Colorado, Georgia, Iowa, Louisiana, Michigan, **Mississippi**, Missouri, **Nevada**, North Carolina, **Oklahoma**, South Carolina, Tennessee, Texas, Utah, and Washington. (16 states)	Alabama, **Alaska**, **Arkansas**, **Idaho**, Kansas, **Montana**, Nebraska, **New Mexico**, **North Dakota**, **South Dakota**, Wisconsin, and **Wyoming**. (12 states)

Note: Predicted change in tax collected predicted to increase or decrease by 5 percent or more for states in boldface.

Table 5.14 Percent Change in VMT and Total Federal Tax Collected in States

	Flat MBUF, Federal		Flat MBUF, Increased	
	Percent Change in:		Percent Change in:	
	VMT	Federal Tax Collected	VMT	Federal Tax Collected
Alabama	-0.10	-2.09	-0.13	-2.26
Alaska	0.03	-6.44	0.04	-6.27
Arizona	-0.03	-3.51	-0.04	-3.59
Arkansas	0.09	-7.00	0.12	-6.77
California	-0.16	2.05	-0.23	1.97
Colorado	-0.06	-0.75	-0.08	-0.84
Connecticut	-0.20	5.70	-0.28	5.31
Delaware	-0.18	2.92	-0.25	2.63
District of Columbia	-0.27	2.28	-0.39	2.24
Florida	-0.16	0.70	-0.22	0.63
Georgia	-0.10	-1.08	-0.14	-1.11
Hawaii	-0.18	4.73	-0.26	4.76
Idaho	-0.13	-6.21	-0.17	-6.18
Illinois	-0.19	5.08	-0.27	5.04
Indiana	-0.10	0.27	-0.14	0.25
Iowa	-0.05	-4.44	-0.06	-4.49
Kansas	-0.02	-2.94	-0.03	-2.84
Kentucky	-0.06	0.60	-0.08	0.42
Louisiana	-0.17	-0.28	-0.22	-0.40
Maine	-0.14	0.35	-0.20	0.16
Maryland	-0.30	5.50	-0.43	5.53
Massachusetts	-0.18	3.71	-0.27	4.06
Michigan	-0.04	-2.94	-0.06	-2.87
Minnesota	-0.15	3.26	-0.23	3.36
Mississippi	0.03	-5.59	0.04	-5.77
Missouri	-0.08	-0.41	-0.11	-0.61
Montana	-0.01	-6.93	-0.01	-6.74
Nebraska	-0.01	-3.96	-0.01	-4.06
Nevada	-0.23	-5.13	-0.33	-5.04
New Hampshire	-0.16	6.52	-0.22	6.26
New Jersey	-0.14	4.15	-0.21	4.46
New Mexico	0.04	-6.41	0.06	-6.30
New York	-0.19	4.29	-0.28	4.22
North Carolina	-0.11	-2.85	-0.16	-2.98
North Dakota	0.03	-9.84	0.05	-9.72
Ohio	-0.10	1.08	-0.14	1.12
Oklahoma	-0.03	-5.05	-0.03	-5.33
Oregon	-0.14	1.21	-0.19	1.01
Pennsylvania	-0.16	2.01	-0.22	1.76
Rhode Island	-0.22	6.68	-0.31	6.29
South Carolina	-0.10	-2.48	-0.14	-2.54
South Dakota	0.04	-9.98	0.07	-10.07
Tennessee	-0.09	-2.13	-0.12	-2.10
Texas	-0.07	-2.74	-0.09	-2.77
Utah	-0.07	-2.01	-0.10	-2.11
Vermont	-0.24	5.38	-0.34	5.28
Virginia	-0.11	0.79	-0.15	0.72
Washington	-0.08	-2.74	-0.13	-2.59
West Virginia	-0.09	1.58	-0.12	1.29
Wisconsin	-0.10	-1.01	-0.14	-1.07
Wyoming	0.10	-9.56	0.15	-9.68
Total	-0.12	-0.12	-0.16	-0.16

Notes: Donee states, those states whose share of federal-aid transportation funding exceeds their share of contributions to the HTF, are highlighted.

SENSITIVITY ANALYSIS

There are many actual and potential sources of bias in the study methodology. A sensitivity analysis permits some of these to be examined by using alternative sources of data or alternative methodological approaches.

Results Using Alternative Data

The NHTS data includes alternative variables for VMT and MPG. In addition, the EIA has alternative fuel price surveys which result in different estimates of fuel prices than the fuel price variable included with the NHTS (US EIA 2011b, 2011c). All of these variables, including the variables used in the primary analysis and other, alternative variables, have biases and errors. Because of the possibility that the results may be sensitive to bias and error, the analysis was replicated using five alternative sets of data where one or more variables were replaced with an alternative. These are:

- Replace the ORNL estimate of annual VMT with the survey respondent estimate when available,
- Replace the fuel price variable with an alternative EIA data series,
- Replace both the VMT variable and the fuel price variable,
- Ignore other types of vehicles than cars, vans, SUVs, and pickups,
- Replace the EIA on-road vehicle fuel economy estimate with the EPA combined fuel economy rating.

Key summary statistics for the alternative data are presented in Table 5.15. The data are quite similar with several critical distinctions. The VMT variable estimated by ORNL is higher than the survey respondent's own estimates (US FHWA 2004b, 2011).[65] Respondents did not always provide an estimate of annual VMT for every household vehicle. ORNL was able to make VMT estimates for several thousand of these vehicles and there are consequently more observations in the primary data. The average price per mile of travel is about 5 percent higher when calculated using the alternative EIA fuel price data than when calculated using the primary fuel price variable in the NHTS. This could be due to either differences in the price survey methodologies or differences in weighting the price data to calculate an annual average for each household. Surprisingly, dropping heavy trucks, RVs, motorcycles and unknown vehicle types had little effect on VMT and MPG. However, the number of observations is higher because the types of vehicles dropped were more likely to have missing values for at least one characteristic and so, ironically, more households could be included in this data set. Lastly, replacing the estimated on-road MPG with the higher EPA fuel economy ratings increases the average household MPG and reduces the average per mile price. Also, because there is no need for additional information to adjust the fuel economy ratings, the sample size of this data set is larger.

The Suits indices for all of the alternatives, calculated using the alternative data sets, are compared in Table 5.16. The Suits index is sensitive to different estimates of VMT, but this alternative variable does not affect the findings. In all alternative data sets, the Suits index for the equivalent flat rate MBUFs are just marginally more regressive. But the difference is so small, just 0.002 for most alternative data sets, that it cannot be characterized as significant.

The average changes in consumer surplus for the population and for key groups are presented in Table 5.17. This table compares the results calculated by all of the alternative data sets

[65] Details about the ORNL methodology are provided in the Technical Appendix.

side by side for each alternative. Because of space constraints and to ease the burden on the reader of looking at so many numbers, only four MBUF alternatives are included on the table, which nonetheless spans two pages. The first page compares the equivalent flat rate MBUFs. The second page compares two rate increases, the 50 percent increase in the federal fuel tax and the 1 cent MBUF added to the existing fuel taxes.

Replacing the on-road MPG with the EPA city/high fuel economy ratings has the effect of not only increasing average MPG, reducing the average cost per mile, as noted in Table 5.15 but also of changing the distribution of fuel efficiency in the population. This is evident by the change from a net positive average change in consumer surplus for the equivalent MBUF to a net negative change in consumer surplus. The method of calculating the equivalent rate, as described in Chapter 4, is to divide total tax collected by total VMT as this is done for each of the alternate data sets so that the flat-rate MBUF in each is slightly different (all are approximately 0.9 cents per mile). Other than this difference, however, it is clear that the winning and losing groups are insensitive to alternate variables. Rural and retired households have gains in consumer surplus while urban, second city, and suburban households have a loss in consumer surplus. Middle income households have the largest increase in consumer surplus for the income groups, reflecting the insignificant impact of replacing the fuel tax with an equivalent MBUF on income equality.

Increasing the tax rate has a uniform outcome across all results for all data sets, including the replace MPG variable data set. This illustrates how the small distributional impact that replacing the fuel tax with an MBUF is likely to have. The differences between groups in the equivalent rate MBUF all become rather small in magnitude when the rate is increased. In Table 5.17, the patterns are unchanged, with rural households and households with children having the largest declines in consumer surplus. The key finding from this chart, however, is that the results are clearly robust to alternate variables.

Table 5.15 Summary Statistics of Alternative Data

	Primary Data	Replace VMT Variable	Replace Price Variable	Replace Price & VMT Variables	Light Vehicles Only	Replace MPG Variable
Annual VMT (miles)	23,101	20,700	23,101	20,700	22,825	23,049
MPG	21.1	21.0	21.1	21.0	21.1	25.9
Price per Mile (cents)	15.32	15.43	16.13	16.25	15.31	12.43
Income ($)	72,567	73,805	72,567	73,805	72,576	72,493
Household Size	2.54	2.51	2.54	2.51	2.55	2.54
Number of Observations	125,936	117,936	125,936	117,936	126,223	126,694

Table 5.16 Suits Indices Calculated Using Alternative Data

	Primary Data	Replace VMT Variable	Replace Price Variable	Replace Price & VMT Variables	Light Vehicles Only	Replace MPG Variable
Current, 2008-09	-0.303	-0.274	-0.298	-0.269	-0.305	-0.299
Flat MBUF, federal only	-0.304	-0.275	-0.298	-0.269	-0.305	-0.301
Flat MBUF, state only	-0.304	-0.275	-0.299	-0.270	-0.305	-0.302
Flat MBUF, state & federal	-0.304	-0.276	-0.299	-0.270	-0.305	-0.304
Increased fuel tax	-0.302	-0.273	-0.297	-0.269	-0.303	-0.300
Increased flat MBUF	-0.301	-0.273	-0.297	-0.268	-0.302	-0.302
1 cent MBUF	-0.298	-0.271	-0.294	-0.267	-0.299	-0.301
Tiered MBUF	-0.288	-0.255	-0.285	-0.253	-0.291	-0.289
17.7 cent MBUF	-0.252	-0.240	-0.252	-0.239	-0.255	-0.312

Alternative Price Elasticity Assumptions

The change in a household's demand for VMT with respect to the change in price is measured by the price elasticity of demand for travel. In this model, the price elasticity varies by household with income and characteristics of the household's vehicle stock. Estimated household price elasticity, as described in Chapter 3, has a mean of -0.43 with a range of -0.98 to 0.02 and an interesting bi-modal distribution.

The assumption that price elasticity varies is based on a modern body of research (Blundell, Horowitz, and Parey 2011; Wadud, Graham, and Noland 2009; Bento et al. 2009; West 2005). It is also possible, however, to assume that the price elasticity is constant among households. It is instructive to examine the results using alternative price elasticity assumptions, one more elastic than the mean estimated elasticity and the other less elastic. The first is unit elasticity, -1, which means that consumers reduce travel in direct proportion to the increase in price. The second is -0.22 which is drawn from Parry and Small (2005) and is consistent with much of the literature.

The average changes in consumer surplus, calculated using these alternative price elasticity assumptions, are compared in Table 5.18 for four of the MBUF alternatives. It is clear that the assumption about price elasticity can have strong implications for the findings of this study.

In particular, the equity implications for whether an MBUF might be regressive or progressive can be strongly affected but the assumption. A flat-rate MBUF increases the consumer surplus of low income households by a small amount regardless of the price elasticity assumption. High income households, on the other hand, have a similar small but positive increase in their consumer surplus when their price elasticity is assumed to be inelastic. However, under the constant unit elasticity assumption, high income households are estimated to have a large decrease in consumer surplus. If, in fact, high-income households are more responsive to changes in price than the model has estimated, an MBUF could be relatively more progressive than the fuel tax. We discussed above how any increase n the tax rate, regardless of whether it is an MBUF or a fuel tax, has the effect of reducing the regressivity of this tax. This observation is unaffected by the price elasticity assumption.

The findings for other groups are much less sensitive to the price elasticity assumption. The changes in consumer surplus among life cycle groups and community types calculated using alternative constant price elasticities are consistent with the change calculated using the elasticity estimated by the model. The primary difference is that the higher the price elasticity is, the greater the loss in consumer surplus from an increase in the tax rate.

Table 5.17 Average Change in Consumer Surplus Using Alternative Data (Page 1)

	Flat MBUF, State & Federal						Increased Flat MBUF					
	Primary Data (dollars)	Replace VMT Variable (dollars)	Replace Price Variable (dollars)	Replace Price & VMT Variables (dollars)	Light Vehicles Only (dollars)	Replace MPG Variable (dollars)	Primary Data (dollars)	Replace VMT Variable (dollars)	Replace Price Variable (dollars)	Replace Price & VMT Variables (dollars)	Light Vehicles Only (dollars)	Replace MPG Variable (dollars)
Population Average	5.06	3.15	5.24	3.44	5.92	-0.91	3.28	1.86	2.87	1.62	3.99	-0.76
Population Thirds												
Low Income	3.91	2.90	3.90	3.04	4.37	-2.41	2.74	2.09	2.45	1.93	3.13	-1.50
Middle Income	6.25	3.97	6.62	4.25	7.77	-0.12	4.79	2.83	4.32	2.52	5.78	0.55
High Income	5.01	2.58	5.21	3.02	5.61	-0.19	2.30	0.67	1.83	0.41	3.05	-1.33
Household Life Cycle												
Household with children	5.54	3.68	5.93	4.21	6.29	2.46	3.39	1.99	2.90	1.71	4.12	1.35
Retired household	8.35	6.99	9.06	7.80	8.40	-1.47	5.80	4.79	5.51	4.63	5.91	-0.92
Other households	2.32	0.02	1.94	-0.27	3.84	-3.58	1.41	-0.28	0.99	-0.54	2.52	-2.57
Community Type												
Urban	-2.30	-1.97	-2.22	-1.75	-1.05	-8.14	-2.68	-2.38	-2.96	-2.53	-1.58	-6.87
Second City	-1.02	-0.75	-1.19	-0.67	0.75	-7.49	-0.72	-0.67	-1.05	-0.86	0.62	-5.13
Suburb	-1.67	-1.15	-1.48	-0.81	-0.53	-7.81	-2.45	-1.99	-2.82	-2.22	-1.33	-6.75
Rural	15.12	9.71	15.51	10.10	15.23	9.43	11.17	7.17	10.64	6.86	11.18	7.53

Table 5.17 Average Change in Consumer Surplus Using Alternative Data (Page 2)

	Increased Fuel Tax						Add 1 Cent MBUF					
	Primary Data (dollars)	Replace VMT Variable (dollars)	Replace Price Variable (dollars)	Replace Price & VMT Variables (dollars)	Light Vehicles Only (dollars)	Replace MPG Variable (dollars)	Primary Data (dollars)	Replace VMT Variable (dollars)	Replace Price Variable (dollars)	Replace Price & VMT Variables (dollars)	Light Vehicles Only (dollars)	Replace MPG Variable (dollars)
Population Average	-77.85	-66.31	-75.51	-66.25	-73.84	-68.46	-170.46	-148.33	-169.89	-148.36	-166.37	-184.61
Population Thirds												
Low Income	-36.52	-27.69	-36.43	-27.68	-35.38	-34.72	-80.84	-60.71	-80.79	-60.79	-79.52	-94.63
Middle Income	-76.46	-63.87	-76.05	-63.80	-74.38	-69.42	-170.24	-141.88	-169.55	-141.91	-165.77	-185.72
High Income	-114.57	-107.29	-114.02	-107.21	-111.28	-101.17	-260.30	-242.25	-259.27	-242.22	-253.72	-273.36
Household Life Cycle												
Household with children	-106.12	-90.75	-105.56	-90.64	-103.48	-96.37	-239.57	-203.57	-238.55	-203.49	-234.41	-257.82
Retired household	-44.20	-37.57	-44.10	-37.58	-42.99	-38.70	-96.29	-81.17	-96.22	-81.32	-94.02	-104.76
Other households	-70.46	-64.63	-70.14	-64.57	-68.46	-63.91	-159.48	-146.07	-158.97	-146.12	-155.03	-173.98
Community Type												
Urban	-45.42	-39.44	-45.39	-39.54	-44.63	-41.30	-105.27	-90.66	-105.35	-91.00	-103.30	-116.83
Second City	-63.46	-53.86	-62.18	-53.84	-60.96	-56.47	-142.71	-122.03	-142.27	-122.10	-139.16	-156.15
Suburb	-75.80	-68.30	-75.50	-68.30	-74.16	-68.09	-174.80	-155.85	-174.30	-156.00	-171.28	-189.05
Rural	-95.29	-82.26	-94.75	-82.09	-92.29	-86.00	-208.97	-180.41	-208.01	-180.23	-203.31	-224.50

Table 5.18 Average Change in Consumer Surplus Using Alternative Price Elasticities

	Flat MBUF, State & Federal			Increased Flat MBUF			Increased Fuel Tax			Add 1 Cent MBUF		
	Estimated Elasticity (dollars)	Unit Price Elastic (dollars)	-0.22 Price Elasticity (dollars)	Estimated Elasticity (dollars)	Unit Price Elastic (dollars)	-0.22 Price Elasticity (dollars)	Estimated Elasticity (dollars)	Unit Price Elasticity (dollars)	-0.22 Price Elasticity (dollars)	Estimated Elasticity (dollars)	Unit Price Elastic (dollars)	-0.22 Price Elasticity (dollars)
Population Average	5.06	-11.35	6.02	3.28	-9.44	4.03	-75.85	-308.10	-69.36	-170.46	-700.04	-155.36
Population Thirds												
Low Income	3.91	4.12	4.21	2.74	2.80	3.02	-36.52	-97.36	-22.35	-80.84	-216.94	-48.77
Middle Income	6.25	1.51	8.38	4.79	2.55	6.35	-76.46	-283.20	-64.25	-170.24	-633.81	-141.61
High Income	5.01	-39.68	5.48	2.30	-33.67	2.71	-114.57	-543.70	-121.47	-260.30	-1,249.27	-275.68
Household Life Cycle												
Household with children	5.54	-24.05	5.97	3.39	-19.32	3.76	-106.12	-457.97	-102.54	-239.57	-1,044.41	-231.33
Retired household	8.35	14.46	8.17	5.80	9.52	5.73	-44.20	-155.38	-35.97	-96.29	-342.62	-77.82
Other households	2.32	-17.84	4.57	1.41	-13.71	3.08	-70.46	-278.59	-62.54	-159.48	-636.78	-140.49
Community Type												
Urban	-2.30	-26.81	-0.87	-2.68	-22.99	-1.48	-45.42	-167.56	-37.66	-105.27	-393.44	-87.00
Second City	-1.02	-28.98	0.36	-0.72	-20.14	0.33	-62.46	-244.28	-54.42	-142.71	-563.89	-123.91
Suburb	-1.67	-38.05	0.17	-2.45	-32.00	-1.06	-75.80	-317.93	-70.49	-174.80	-739.23	-161.89
Rural	15.12	19.61	15.15	11.17	15.03	11.20	-95.29	-392.63	-89.33	-208.97	-872.27	-195.59

6. FUTURE DISTRIBUTIONAL IMPLICATIONS, 2010 - 2030

KEY FINDINGS

The distributional implications of fuel taxes and MBUFs are not found to change over future years. However, both fuel taxes and MBUFs could become more or less regressive over time given some macroeconomic and regulatory changes. This is ultimately the result of changes in overall fuel consumption with respect to the rate of real income growth. The lack of a significant difference between the regressivity of the fuel tax and an equivalent flat-rate MBUF does not change under any scenario. Constant increases in household fuel economy appear to slightly make the MBUF less regressive, but the difference is very small. Increasing the fuel economy of more efficient households faster than less efficient households results in the MBUF becoming slightly more regressive. As previously found, however, the change is too slight to be significant. All other findings identified in the preceding chapter are robust to scenario assumptions over time.

MBUFS PROVIDE REVENUE SUSTAINABILITY

Projecting annual household VMT, fuel consumption and revenue 2010-2030 illustrates how a flat rate MBUF, even if it is not routinely adjusted for inflation, can stabilize the degradation of the tax base from improving vehicle fuel economy. Figure 6.1 plots projected VMT, with the current fuel tax, for the reference case and three other scenarios. All increase with assumptions of continued growth in population and income. High oil prices increase the cost of driving and reduce household demand for VMT; these are the lower bound on VMT estimates. Low oil prices, on the other hand, reduce the cost of driving and increase household demand for driving; this scenario generates the upper bound on VMT estimates. In between, a scenario that continues to increase fuel economy standards by 6 percent each year, follows the reference case at first, but diverges upwards in 2020 as the fuel economy of the population of vehicles become far more efficient than the reference case. Illustrating the rebound effect, better fuel efficiency reduces the marginal cost of driving, which increases demand.

As shown in Figure 6.2, which plots projected fuel consumption for the same four scenarios, fuel consumption is flat for the reference case and falls over the improved CAFE standards scenario. By 2030, households in the improved CAFE standards scenario consume 6.7 percent less fuel than the high oil price scenario but travel 18 percent more. Highlighting the problem with the unsustainability of the current fuel tax rate as an adequate long-term source of transportation revenue, fuel consumption in the CAFE improvement scenario falls by 16 percent while VMT grows by 41 percent. Improving fuel economy is important but it is necessary for the government to also consider how to replace revenue and to manage demand.

Figure 6.3 presents estimates of the average tax rate per mile for current fuel taxes, the flat rate MBUF that is set at an equivalent rate in 2009, and two alternative MBUFs. All of the taxes fall in real value over time with inflation, but the divergence between the fuel tax and its equivalent MBUF illustrates the impact of continuing improvements in vehicle fuel economy, under existing policy, will erode the real value of the fuel tax over time. The reference case is a conservative projection; it makes no assumptions that any additional energy policy that is not already in effect will

Figure 6.1 Projections of VMT, 2010 - 2030

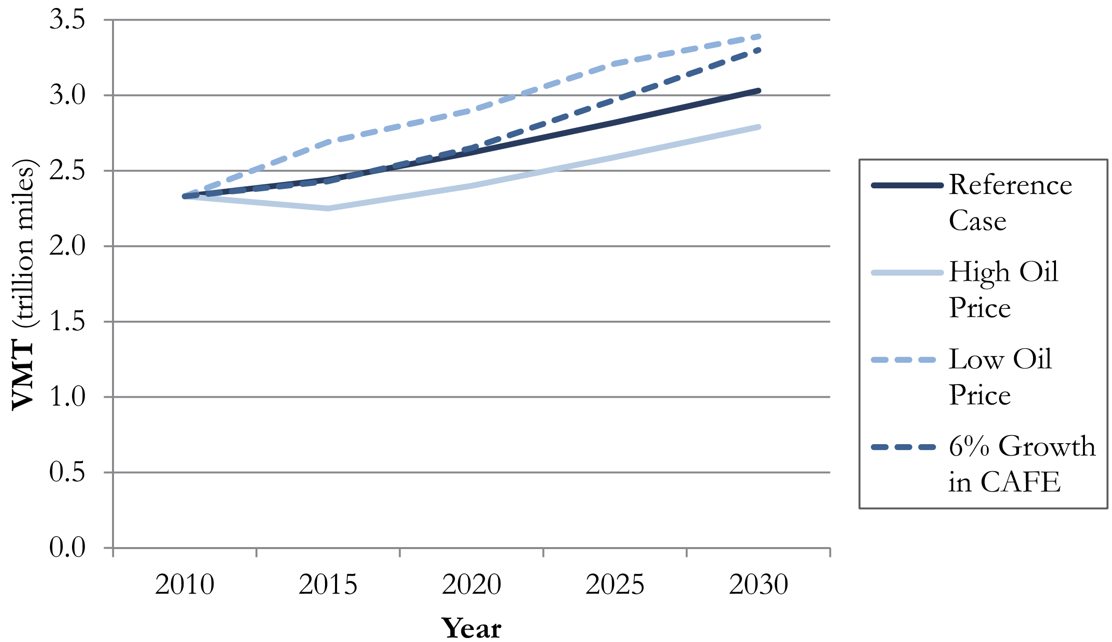
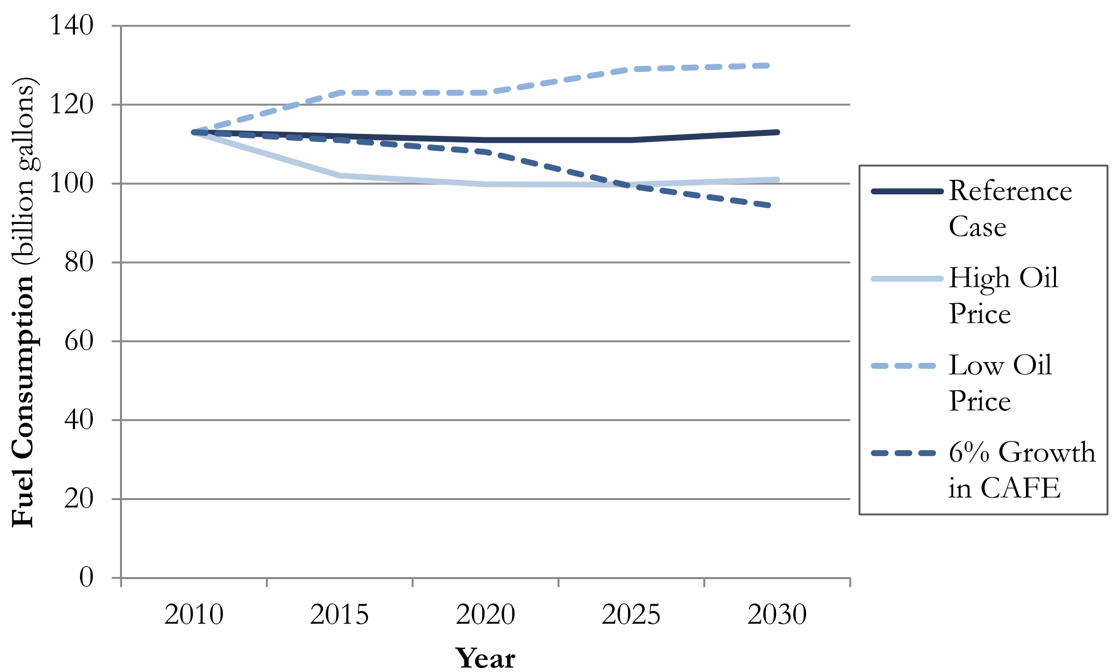


Figure 6.2 Projections of Fuel Consumption, 2010 - 2030



be enacted. Figure 6.4 completes the picture with projections of tax revenue (not accounting for administration and collection costs) for the MBUF policy alternatives that are projected. The 1 cent MBUF policy adds the MBUF to the existing fuel tax and so it falls at a rate between the fuel tax and the equivalent MBUF. A 1 cent per mile MBUF would generate an additional $22 billion per year in 2010 that would decline to $17 billion per year despite higher VMT due to inflation. The tiered MBUF in these projections is, for simplicity, assumed to adjust every year to generate constant real revenue, before inflation, despite improvements in vehicle fuel economy. A tiered policy might behave more like a fuel tax over time unless it is designed to respond to improving vehicle fuel economy.[66]

NO CHANGE IN MBUF DISTRIBUTIONAL IMPLICATIONS

The primary purpose of projecting the MBUF alternatives over future yeas and under different scenarios is to determine whether or not the distributional implications of MBUFs might change over time, and to better determine the factors that influence these changes. Table 6.1 presents projections of Suits indices for the federal fuel tax and each of the three MBUF alternatives modeled in the eight scenarios. As found previously, the Suits indices for the fuel tax and the equivalent flat rate MBUF are essentially identical in each year of each scenario.

The projected Suits indices are different, however, in different scenarios. These results illustrate how household demand for VMT, and only by extension the equity of transportation taxes, are determined more by the per mile cost of fuel than by the per mile tax rate. As found previously, higher costs per mile (whether because of higher tax rates, higher oil prices, or lower fuel economy) reduce the demand in low income households by a larger amount than in high income households and this reduces the tax burden in low income households by more than in high income households. Regardless of whether this is actually fairer, higher costs result in a lower Suits index. Low oil prices and higher CAFE standards reduce the cost of driving and low income households will increase their VMT by more than high income households increase their VMT because they are more sensitive to changes in price. This increases the tax burden in low income households by more than in high income households resulting in a relatively higher Suits index for all of the transportation taxes.

These results clearly illustrate why it is necessary to account for changes in VMT in addition to the change in tax burden when discussing the distributional implications of transportation taxes and user fees. Table 6.2 presents the projected changes in consumer surplus for each of the three MBUF alternatives modeled. The fuel tax is falling in real terms with both inflation and improving fuel economy. Therefore all of the alternatives are equivalent to a tax rate increase after 2010. Consequently the change in consumer surplus, between the fuel tax and the alternative in each year, is appropriately negative. For each alternative, 2015-2030, average VMT is rising and average tax burden is falling, but it is falling faster for the fuel tax.

Consistent with the findings in the previous chapter, however, the flat-rate MBUF alternatives are not clearly more or less regressive than the fuel tax Table 6.3 presents the average

[66] The tiered fee is levied per vehicle, but the analysis occurs at the household level. Household fuel economy and travel costs can be adjusted, but vehicle choice is "baked in." A tiered policy would likely have other impacts on vehicle choice which should be modeled in future research.

Figure 6.3 Projections of Federal Tax Rate per Mile, Current Gasoline Tax and Alternatives, 2010 – 2030

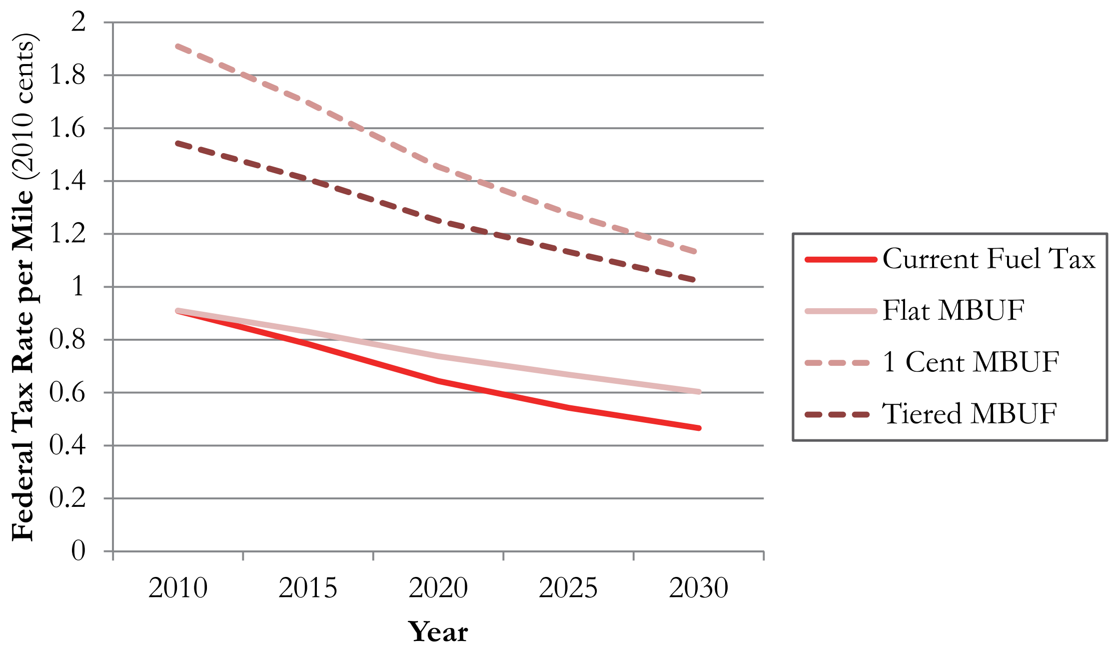


Figure 6.4 Projections of Federal Tax Revenue, Current Gasoline Tax and Alternatives, 2010 - 2030

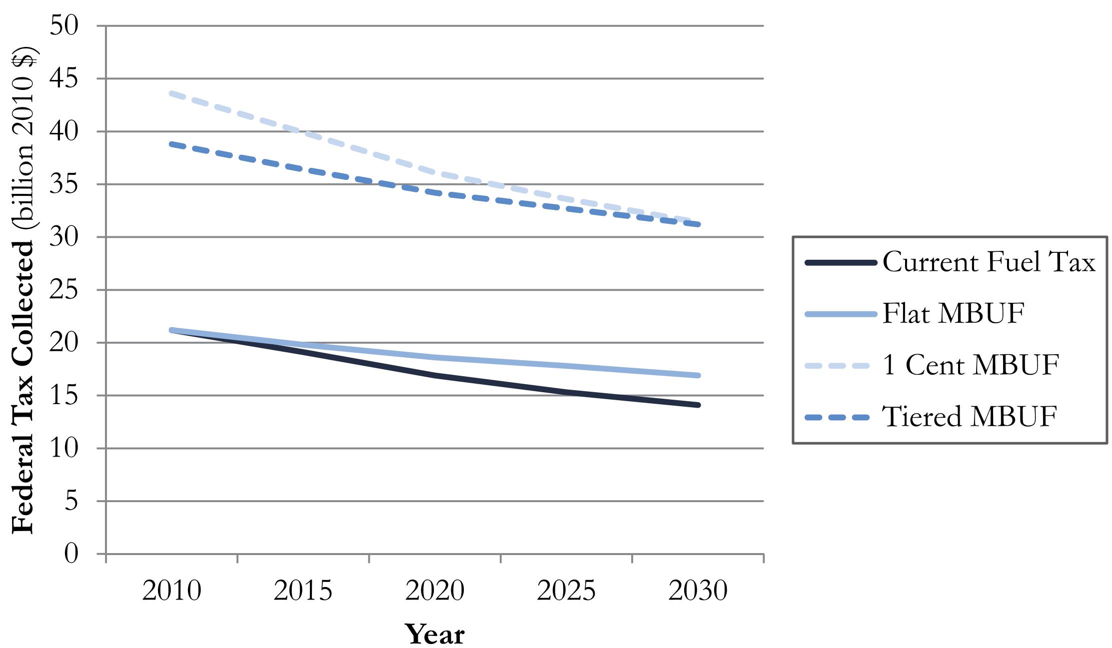


Table 6.1 Projections of Suits Indices for MBUF Alternatives, 2010 - 2030

	Current Federal Fuel Taxes	Flat-Rate MBUF, Federal	Add 1 Cent MBUF	Tiered MBUF
2008-09	-0.303	-0.304	-0.298	-0.288
Reference Case				
2010	-0.296	-0.296	-0.291	-0.281
2015	-0.291	-0.291	-0.287	-0.276
2020	-0.292	-0.292	-0.288	-0.277
2025	-0.295	-0.294	-0.291	-0.279
2030	-0.297	-0.296	-0.293	-0.281
High Growth				
2015	-0.291	-0.291	-0.286	-0.276
2020	-0.291	-0.291	-0.287	-0.276
2025	-0.292	-0.292	-0.288	-0.276
2030	-0.295	-0.294	-0.291	-0.278
Low Growth				
2015	-0.292	-0.292	-0.287	-0.277
2020	-0.294	-0.293	-0.290	-0.279
2025	-0.296	-0.295	-0.292	-0.280
2030	-0.299	-0.299	-0.296	-0.283
High Oil Price				
2015	-0.273	-0.273	-0.270	-0.260
2020	-0.272	-0.271	-0.268	-0.258
2025	-0.274	-0.273	-0.271	-0.260
2030	-0.276	-0.276	-0.273	-0.262
Low Oil Price				
2015	-0.313	-0.313	-0.307	-0.296
2020	-0.316	-0.315	-0.310	-0.298
2025	-0.325	-0.325	-0.320	-0.307
2030	-0.326	-0.325	-0.321	-0.307
Extend Policies				
2015	-0.291	-0.291	-0.286	-0.276
2020	-0.294	-0.294	-0.290	-0.279
2025	-0.303	-0.302	-0.299	-0.286
2030	-0.310	-0.309	-0.306	-0.292
6% CAFE Growth				
2015	-0.291	-0.291	-0.286	-0.276
2020	-0.295	-0.295	-0.291	-0.279
2025	-0.307	-0.306	-0.302	-0.289
2030	-0.319	-0.317	-0.314	-0.298
Skew Distribution				
2015	-0.294	-0.294	-0.290	-0.278
2020	-0.297	-0.297	-0.293	-0.279
2025	-0.300	-0.301	-0.297	-0.281
2030	-0.303	-0.305	-0.301	-0.282

Table 6.2 Projections of Changes in Consumer Surplus, 2010 - 2030

	Average Change in Consumer Surplus (2010 dollars)		
	Flat-Rate MBUF, Federal	Add 1 Cent MBUF	Tiered MBUF
Reference Case			
2010	1.89	-165.30	-125.07
2015	-5.88	-147.99	-120.01
2020	-14.09	-132.32	-115.99
2025	-19.68	-121.08	-112.72
2030	-22.01	-110.29	-106.60
High Growth			
2015	-6.20	-151.53	-123.09
2020	-15.27	-140.30	-123.42
2025	-21.54	-130.70	-122.17
2030	-24.79	-122.60	-118.97
Low Growth			
2015	-5.72	-145.29	-117.72
2020	-13.21	-126.42	-110.48
2025	-17.92	-111.87	-103.83
2030	-19.78	-100.18	-96.49
High Oil Price			
2015	-6.23	-135.95	-112.65
2020	-14.31	-120.26	-108.55
2025	-19.71	-109.33	-105.22
2030	-22.09	-99.59	-99.83
Low Oil Price			
2015	-6.03	-162.91	-129.13
2020	-15.09	-146.42	-125.40
2025	-20.35	-137.09	-122.60
2030	-22.32	-123.63	-114.53
Extend Policies			
2015	-5.93	-147.78	-119.93
2020	-16.36	-133.25	-118.80
2025	-30.01	-125.34	-125.49
2030	-36.09	-116.87	-124.50
6% CAFE Growth			
2015	-5.99	-147.79	-119.99
2020	-17.71	-133.68	-120.39
2025	-35.00	-127.21	-131.52
2030	-44.61	-120.92	-135.25
Skew Distribution			
2015	-11.06	-150.05	-124.38
2020	-19.67	-135.09	-119.53
2025	-25.61	-124.57	-115.54
2030	-27.77	-114.10	-108.65

change in consumer surplus for key groups in the reference case.[67] The average change in low income households' consumer surplus is clearly lower than middle and high income households. These results are entirely consistent with the distributional implications previously identified and do not appear to change significantly over time among the scenarios. There are differences between the scenarios, of course, based on differences in assumptions regarding fuel prices and vehicle MPG as discussed above.

The "equivalent" flat-rate MBUF is only equivalent in real terms in 2009. After that year, it begins to increase relative to the fuel tax because of improving vehicle fuel economy. This is important to understand when examining the projected changes in consumer surplus for key groups because it is not possible to meaningfully separate the effect of a rate increase from the change from charging by the gallon to charging by the mile. As discussed previously, any rate increase will increase the tax burden of households with children and rural households because the average VMT of these groups are significantly higher. While MBUFs will always reduce the tax rate per mile for inefficient vehicles relative to an equivalent rate fuel tax, the total real tax burden increases as the rate per mile increases relative to the fuel tax. The fuel economy of all vehicles improves at a constant rate in all scenarios except the "skew distribution" scenario. In the skewed MPG distribution scenario, presented in Table B.8, the consumer surplus for rural households also increases relative to households in other areas, but at a lower rate. This is also true for the low oil price scenario in which vehicle MPG grows most slowly of all the scenarios.

FUEL PRICE AND FUEL ECONOMY MATTER MORE THAN TAX RATE

While the tax rate structure of a transportation user fee or tax does affect equity, the projections illustrate that changes in the price of oil and vehicle fuel economy have a greater impact on the equity of the fuel tax or any alternative travel-related tax such as MBUFs. Future research to determine the equity implications of any specific MBUF proposals will need to examine the effects of rate structure on household vehicle choice. Further, it is still necessary to understand how the mass adoption of alternative fuel vehicles may affect the equity of transportation finance. These projections assume that improvements in vehicle fuel economy will be available in vehicles at all price levels. This is clearly not the case as the most efficient vehicles, HEVs and EVs, carry a significant price premium and will be available primarily to high income households (Ackerman and Stanton 2011).

[67] The interested reader can find projections of average changes in consumer surplus for the other seven scenarios in Appendix B.

Table 6.3 Projections of Changes in Group Consumer Surplus, Reference Case, 2015 - 2030

	Flat MBUF, Federal (2010 dollars)				Add 1 Cent MBUF (2010 dollars)				Tiered MBUF (2010 dollars)			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
Population Average	-5.88	-14.09	-19.68	-22.01	-147.99	-132.32	-121.08	-110.29	-120.01	-115.99	-112.72	-106.60
Population Thirds												
Low Income	-2.07	-5.97	-8.70	-9.91	-67.37	-60.57	-55.91	-51.31	-43.38	-43.01	-42.72	-41.02
Middle Income	-5.08	-13.37	-19.05	-21.47	-146.62	-131.23	-120.27	-109.70	-116.70	-113.11	-110.24	-104.49
High Income	-10.49	-22.93	-31.30	-34.66	-229.97	-205.16	-187.06	-169.85	-199.93	-191.83	-185.18	-174.29
Household Life Cycle												
Household with children	-9.01	-20.47	-28.24	-31.42	-209.44	-187.09	-170.96	-155.51	-187.14	-179.48	-173.38	-163.35
Retired household	-1.14	-6.11	-9.53	-11.06	-82.50	-73.89	-67.80	-61.90	-58.51	-57.38	-56.40	-53.74
Other households	-6.36	-13.87	-19.00	-21.11	-137.90	-123.37	-112.99	-102.99	-101.95	-99.23	-96.92	-91.96
Community Type												
Urban	-6.25	-10.81	-13.93	-15.13	-90.32	-80.85	-74.14	-67.66	-55.88	-55.15	-54.45	-52.01
Second City	-6.85	-13.35	-17.79	-19.57	-123.18	-110.22	-100.98	-92.07	-85.94	-83.99	-82.31	-78.26
Suburb	-9.19	-17.06	-22.41	-24.50	-152.03	-135.90	-124.31	-113.18	-111.13	-108.04	-105.41	-99.90
Rural	-3.29	-14.06	-21.41	-24.62	-182.04	-162.71	-148.80	-135.46	-168.92	-161.95	-156.45	-147.42

7. CONCLUSION

The purpose of this dissertation is to examine the equity implications of replacing fuel taxes with an MBUF. A flat-rate MBUF is no more or less regressive than a fuel tax. While some metrics suggest that a flat-rate MBUF would be somewhat more regressive that the gasoline tax, others suggest that a flat-rate MBUF would be somewhat more progressive. Replacing the gasoline tax with a flat-rate MBUF increases the tax burden of households in urban areas and reduces the tax burden of retired households and households in rural areas. The extensive sensitivity analysis used in this research allows for a high degree of confidence in these findings. Overall, transitioning from a fuel tax to an MBUF with an equivalent rate would not significantly change the cost of driving for most Americans.

DISCUSSION OF FINDINGS

Replacing the fuel tax with an MBUF has little impact on the overall equity of collecting revenue used for the improvement of the surface transportation system in the U.S. relative to a household's ability to pay. These findings clarify how a decrease or increase the cost of driving, as a result of a change in the tax rate, a change in vehicle fuel economy, or a change in the price of oil, has more influence on the equity of transportation finance than whether drivers are charged by the gallon of gas or by the mile. An increase in the MBUF rate or gasoline tax rate makes it less regressive because low income households are more sensitive to changes in price and reduce VMT accordingly. This may understate the relative change in tax burden because the value of travel that must no longer be taken may not be accurately reflected by the estimated economic value. Other low income households will be unable to easily reduce VMT and may not have a realistic alternative to driving available.

The winners and losers of MBUFs identified in this study, those whose tax burdens respectively decrease or increase, are consistent with prior research. The majority of retired households and households in rural areas are winners because the adoption of an equivalent flat-rate MBUF would reduce their relative tax burdens. The majority of urban and suburban households are losers because their relative tax burdens increase. Households with children are more difficult to characterize as a group because they drive more than other types of households but do not exhibit a clear pattern of vehicle fuel economy. Consequently, households with children that own fuel efficient vehicles are relatively big losers, while households with inefficient vehicles are relatively big winners.

Jurisdictional winners and losers of adopting MBUFs may conflict with the winning and losing groups. While rural households generally benefit from MBUFs, and urban households generally harmed, political support for MBUFs appears to be coming from urbanized states and there is documented opposition to MBUFs by representatives of rural states. Support for MBUFs may be driven by the need for new sources of transportation funding or interest in new demand management strategies to reduce urban traffic congestion. Opposition for MBUFs, on the other hand, may be driven by concerns and uncertainty about how additional funding may be distributed among the states. A flat-rate MBUF would reduce the share of federal revenue contributed by rural states which would make it challenging for representatives from those states, regardless of their donor or donee status, to maintain their current level of federal-aid highway funding. On the other hand, representatives of urban states are in an improved political position because their share of contributions would likely increase.

The results are robust across many different assumptions, but there are significant uncertainties that could impact the interpretation of these results and, perhaps eventually, the actual distributional implications of MBUFs. The policy considerations discussed below address how the equity of MBUFs may be affected by different price elasticities for low income households, higher or lower marginal social costs, and higher than predicted administration and collection costs.

In the 2009 NHTS, the distribution of fuel economy among households of different income groups is sufficiently homogenous that adopting a flat-rate MBUF would not make the collection of transportation revenue more or less regressive. An increase in the tax rate would reduce the average tax burden of low income households and possibly improve their welfare. But this depends on the availability of alternative modes and the actual, realized benefit to low income households from the increase in revenue relative to other, higher income households. Lastly, while this study was not designed to explicitly estimate the relative efficiency and efficacy of replacing fuel taxes with MBUFs, the likely higher costs of collecting, administering, and enforcing MBUFs will require an increase in the average tax rate per mile just to maintain net revenue at current levels. This suggests that while adopting an MBUF could improve social welfare in some ways, and improve the fiscal sustainability of transportation revenue in the long-run, it is unclear whether these benefits will offset the necessary increase in the tax rate.

CONTRIBUTIONS TO KNOWLEDGE

This dissertation makes several unique contributions to knowledge. The research updates MBUF equity studies using more recent data and several methodological improvements. In particular, this study improves the methodology of the only prior national-level study of the distributional implications of MBUFs by strongly improving the estimated price elasticities of demand for VMT as described in Chapter 3 (Weatherford 2011). This study is also the first to directly compare the differences in the estimated collection and administration costs between fuel taxes and MBUFs or any other alternative to fuel taxes, a contribution made possible by recent research to estimate those costs by Balducci et al. (2011). Lastly, while most sophisticated distributional analyses of fuel taxes and their alternatives consider the distribution of changes in household welfare, these typically include only the change in consumer surplus and net revenue. This study is one of the first, if not the first, to add the net change in the externalities of driving and fuel consumption to the net change in revenue (Parry, Walls, and Harrington 2007).

LIMITATIONS AND OPPORTUNITIES FOR FURTHER RESEARCH

Household mode and vehicle choice is not simultaneously modeled and this introduces endogeneity bias. Future research should use a multinomial logit approach to simultaneously model the number of vehicles, vehicle type, vehicle fuel economy, and VMT per vehicle. This will require additional data, but will better be able to illustrate changes in household MPG over time and improve estimates of price elasticity. While these are limitations for this model, the results are expected to be robust because prior research found only minor changes in household MPG given the small change in marginal price that most households face (Bento et al. 2009).

EVs are not modeled in this study because there were no EVs in the NHTS. Further, experts do not predict that there will be a sufficient number of EVs produced and sold in the US to have much of an effect on the overall distributional implications of MBUFs (Bedi et al. 2011). Nonetheless, other researchers may wish to explore the potential equity implications of MBUFs under alternative scenarios of EV market potential and adoption rates or other changes in the distribution of MPG which were not modeled in this study.

The marginal costs of congestion and air pollution were not modeled at a regional level. It could be possible for future research to do so in the states and regions that purchased add-on samples, and by making reasonable assumptions in the remainder of the country. Such a study could significantly improve the quality of the social welfare component of the analysis.

Blundell, Horowitz, and Parey (2011) critique parametric models of VMT and fuel demand functions as yielding "misleading estimates of price sensitivity and welfare measures" because they are misspecified. Instead of imposing a parametric shape restriction that has "no basis in economic theory," this paper imposes a Slutsky condition restriction. This research finds that price elasticity may not vary monotonically with income. Instead, both high income households *and low income households* have lower price elasticities than do middle income households (Blundell, Horowitz, and Parey 2011). This finding suggests that increases in price, from a change in the tax rate or otherwise, may cause the fuel tax or alternative MBUF to be more regressive than estimated in this study. While this finding conflicts with that of other research (Bento et al. 2009; West 2005), and cannot be independently verified or refuted in this study, it has some face validity. When the cost of travel is already high relative to other goods, low income households may not have any discretionary travel that can be reduced. So, while VMT may act as a normal good for middle income households, travel may be a necessity for many low income households, especially those without access to alternative modes of travel.

POLICY CONSIDERATIONS

The findings of this dissertation are significant because they suggest that equity considerations based on ability to pay should not be a significant reason to oppose or support the adoption of MBUFs. However, the consistent finding that rural states benefit from replacing fuel taxes with MBUFs is important but does not preclude concern about MBUFs from rural drivers and their representatives. While the results suggest that overall changes in price have greater distributional implications than do replacing the fuel tax with an MBUF, two characteristics of MBUFs can have stronger distributional implications: rate structure and administration and collection costs. Understanding the effects of these can inform policy development and can potentially be used to improve the fairness of collecting transportation revenue across various dimensions.

Redistributive Considerations

These results may understate the impacts on low income households. Their higher price elasticity means low income households trade mobility for consumption of other necessities. Those with alternatives are in a better position, with respect to their budgets. However, low income households with no reasonable alternative to driving face more challenging situations.

Low income households often do not have as much choice as high income households do when purchasing or acquiring a vehicle. A low income household may receive their vehicle from a relative or a charity. They are more likely to purchase an older, used vehicle. Others may need the additional utility of a heavier vehicle such as a pickup truck, SUV or van. Therefore, many low income households will benefit from an MBUF. However, some low income households with a high demand for VMT, may intentionally purchase a high MPG vehicle to control their travel costs. While they will still benefit, under an MBUF, from lower fuel costs, the increase in their tax rate will reduce their mobility and reduce their disposable income. Some policy makers may wish to consider redistributive policies to mitigate these negative impacts and the generally higher regressivity of fuel taxes and MBUFs.

Negative impacts to low income households with access to transit can be mitigated with higher spending on transit. It is more difficult, however, to mitigate the impacts to low income households without access to alternatives though transportation spending. Policy makers may wish to consider refunding the MBUF for low income rural households as an inexpensive way to make transportation finance less regressive.

Environmental Considerations

The flat-rate MBUF draws criticism based on environmental equity concerns. The flat-rate MBUF will obviously increase the tax rate per mile on high MPG vehicles while reducing it on low MPG vehicles. To many advocates of improved energy efficiency and reducing GHG emissions, the flat rate MBUF therefore seems unfair. However, at current tax rates and oil prices the tax rate is a small percentage of the total cost of gasoline. Therefore, the overall price signals still encourage fuel efficiency. While a flat-rate MBUF may slightly work against other federal policy to encourage greater fuel efficiency, the need for a more sustainable tax policy is in part created by the success of CAFE standards and alternative fuel vehicle purchase incentives in reducing the fuel economy of the population of vehicles.

The three alternative rate structures considered in this study illustrate that either increasing the rate of the MBUF or using a tiered rate MBUF structure can successfully reduce fuel consumption or GHG emissions. While increasing the fuel tax is a more efficient and effective means of reducing GHG emissions, it should not preclude the benefits of a mileage based alternative, which is also more efficient at reducing other externalities of driving such as congestion, accidents, and other forms of local air pollution.

The tiered alternative will be an attractive option to many MBUF proponents because it addresses the political pressure to avoid increasing the relative tax rate on efficient vehicles. It can, indeed, be successful in achieving that goal, but it also negates some of the benefits of MBUFs as well as potentially creating other market distortions with MPG notches. A feasible alternative to avoid these potential distortions is to use a continuous rate schedule. Any tiered policy should be designed to adjust the rates and threshold annually so that it remains fiscally sustainable as fuel economy improves.

A more rapid and widespread adoption of premium priced EVs could present a major concern for not only revenue, but also the equity of transportation finance. Were large numbers of high income households to evade highway user taxes and fees by purchasing PHEVs and EVs, not only would revenue fall faster than currently predicted but the burden of maintaining the surface transportation system would fall even more heavily on low income households. Given the current trend of EV adoption in urban areas, especially given concerns about range, the burden would also fall more heavily on rural areas. In this case, replacing the fuel tax with an MBUF would make collecting transportation revenue clearly less regressive, and even more clearly favorable for rural states, in comparison. However, it is not obvious that such large quantities of EVs could be sold given the current price premium. Were the cost of EVs to fall dramatically, large numbers of low cost EVs could make the fuel tax less regressive although this would still not benefit rural states due to range anxiety. A lower cost EV would likely have a smaller and less expensive battery and therefore have an even shorter range. While low income urban drivers could clearly reduce their transportation costs by purchasing inexpensive EVs, any significant increase in the sales of EVs should provide added motivation for an accelerated adoption of MBUFs. In any event, proposals to gradually transition to MBUFs by first charging EVs, such as those in Oregon and Texas, have merit.

Commercial trucks were explicitly not considered in this analysis for lack of data. Commercial trucks should be charged a higher rate based on axle weight. This is not only because of lower fuel efficiency but, especially, because trucks are the primary source of pavement damage. These funds could be hypothecated for highway maintenance on the Interstate system to satisfy political critics.

Administration and Collection Costs

The unknown but undeniably higher costs of MBUFs should give all policy makers pause because the magnitude of the economic value of MBUFs is not obviously greater than the increase in administration and collections costs. In this analysis, the cost differential is significantly greater than the benefits. However, this study was designed to examine the distribution of those costs and benefits, not to accurately estimate the net costs and benefits and the net change in social welfare. Nonetheless, the cost differential raises some equity considerations for MBUF policy.

The increase in costs will likely be offset by charging a higher rate. A higher rate will impact rural and suburban drivers more than others because of their higher demand for daily travel. If the costs of collecting the MBUF are even higher than estimated in this study, which is quite plausible, the tax rate will then need to be increased accordingly just to maintain current levels of spending. Therefore, as administration and collection costs rise, the tax is more likely to inequitably affect rural households, and other groups that drive more such as households with children, because the same amount of revenue could have been raised using a fuel tax with a lower average rate per mile.

As long as the costs are reflected in the distribution of the net revenue, an MBUF could result in less revenue to rural states. It may be possible to address political equity concerns by representatives from rural states by directly controlling the costs of collecting and administering an MBUF by population instead of by VMT. This may, in fact, be reasonable since costs might be proportional to the number of vehicles instead of proportional to VMT. The potential magnitude of initially providing the MBUF infrastructure and then administrating, collecting, and enforcing a technologically sophisticated MBUF could be higher than estimated in this study. Unfortunately, it is not at all clear that the net costs of an MBUF will exceed the net benefits. This study does show that while the equity implications of MBUFs are minimal, some groups, especially rural states, may find that the potential equity benefits of MBUFs could be overwhelmed by an increase in the tax rate to cover higher costs.

A. TECHNICAL APPENDIX

DATA CLEANING

The NHTS required data cleaning to ensure consistency between the 2001 and 2009 surveys and to maximize the number of usable observations. The methodology followed is described here to ensure that the results of the dissertation may be replicated. The methodology used for adjusting the sampling weights to correct for bias introduced by the rules for selecting useable households is also described in this section of the Appendix. The original names assigned by FHWA to the NHTS variables are specified in parentheses following a more descriptive reference and are denoted using the *courier* typeface. The original variable names are specified to avoid ambiguity about which variable has been used in the data analysis. In addition, these variable names are occasionally used in the text when it is more convenient to do so than the use of a more descriptive reference.

Household Characteristics

Household identifier

In the 2001 NHTS, some household identifiers include letters and so the household identifier (`HOUSEID`) is stored as a string variable. Therefore, the household identifier in the 2009 NHTS is converted to a string variable so that the two files may be appended to create one file. There are no duplicate household identifiers between the two surveys.

State household location

Several observations in the 2001 NHTS had miscoded state names (`HHSTATE`) but correct Federal Information Processing Standards (FIPS) codes (`HHSTFIPS`). In addition, the state household location was suppressed for observations in states with a population less than 2 million (US FHWA 2004b). Observations with the state identifiers suppressed did not have the census division (`CDIVMSAR`) suppressed. However, Alaska can be uniquely identified because it is the only state with a population under 2 million in Census Division 9. Households with a suppressed state identifier in Division 9 were identified as being located in Alaska and the state location variables were replaced with their correct values (`HHSTATE = "AL" and HHSTFIPS = "02"`).

No state locations were suppressed in the 2009 NHTS. In order to merge the two files, it is necessary to convert the string variables `HHSTATE` and `HHSTFIPS` into integers in the 2001 NHTS. Instead of replacing the "`XX`" code with a "`.`", four new `HHSTFIPS` codes were created (61, 64, 65 and 68) to disaggregate the observations by their Census Division (1, 4, 5 or 8). This also allows for adding more accurate alternative fuel price estimates.

Claritas urban-rural continuum

The Claritas urban-rural continuum variable (`HBHUR`) is consistent between the 2001 and 2009 NHTS with one exception; the value "`TC`" for "Town & County" in the 2009 NHTS is a combination of "`R`" and "`T`" for "Rural" and "Town" in the 2001 NHTS. For consistency, the values "`R`" and "`T`" are replaced by the value "`TC`" in the 2001 data files.

Race of household respondent

The 2009 NHTS race of household respondent variable (`HH_RACE`) has fewer categories in the 2001 NHTS. The variable name has also changed (`HHR_RACE`). For consistency, a new `HH_RACE` variable is created in the 2001 data files from the `HHR_RACE` variable with categories that are consistent with the 2009 NHTS.

The variable name for Hispanic status of household respondent has also changed from `HHR_RACE` in the 2001 NHTS to `HH_RACE` in the 2009 NHTS and a new, consistent variable is created in the 2001 NHTS.

Household income

Income is converted from a categorical variable to a continuous one using the median of each category. The highest category is > $100,000. The panel study of income dynamics was used to find the average income of households earning more than $100,000 in 2001 and 2008. McMullen et al. (2010) and Weatherford (2011) used an even $150,000, but this failed to account for the increase in real incomes over the period in this highest group.

Vehicle Characteristics and Fuel Prices

Household respondents are asked to list the vehicles owned or available for use by the household and provide for each the vehicle type, make, model, model year, and an odometer reading (two odometer readings were collected in the 2001 NHTS). Respondents are also asked how many miles per year each vehicle is driven and whether it is a "hybrid or alternative fuel vehicle." While this elicits useful information, there is no information collected on the vehicle's engine size or fuel metering (type of fuel used) and no automatic check of the validity of a response.

The 2001 NHTS only has variables for estimated vehicle fuel economy, annual VMT, and fuel price for vehicles in households in the "national" sample and are not provided for the "add-on" households. Observations without national sampling weights (`WTHHNTL`) are dropped from the data.

Make and model

Vehicle make and model codes are stored as string variables in the NHTS and these are converted to integers.

Fuel metering

The EIA assumes that all "other truck" type of vehicle (`VEHTYPE = 5`) use diesel fuel. The EIA further assumes that all "motorcycle," "RV," "refused," "not known," "not ascertained," "golf cart," or "other" use gasoline unless otherwise specified. Electric and CNG, as determined by the EIA, are dropped out of concerns about data reliability and quality. There are many missing values in all vehicle type categories and these are standardized to diesel for "other trucks" and gasoline for all other vehicle types.

Fuel economy

The EIA does not estimate on-road fuel economy for vehicle types other than "car," van," "SUV," and "pickup truck." A fixed estimate is used instead for most vehicles as follows:

- Other truck, 8.5 MPG
- RV, 6.4 MPG
- Motorcycle, 56.5 MPG
- Refused, not known, not ascertained, golf cart, or other, 17.4 MPG

However, as with fuel metering, these have been inconsistently applied with many missing values in all vehicle type categories. These are standardized across the 2009 NHTS. The 2001 NHTS did not have fuel economy estimates and all for RVs. In addition, the estimate for motorcycles in the

2001 NHTS was 50 MPG regardless of year or engine size. These values have been standardized to be consistent with the 2009 NHTS.

Annual VMT

If vehicle type is refused, not known, not ascertained, other truck, RV, motorcycle, golf cart, or other then ORNL does not estimate annual VMT (`BESTMILE`); the respondent estimate (`ANNMILES`) is used instead. While this potentially introduces bias (`ANNMILES` is 9.8 percent lower than `BESTMILE` in the 2009 NHTS and 4.5 percent lower in the 2001 NHTS), it affects fewer than 5 percent of household vehicles. The advantage is that these vehicles can be included in the analysis and not bias the results in other ways.

In the 2001 NHTS, several vehicles had estimates of annual fuel consumption and fuel economy but lacked an estimate of annual VMT. Annual VMT was calculated for these households by multiplying gallons by MPG.

Annual average fuel price and state taxes per gallon

All fuel prices and tax values used in this dissertation are in 2010 cents per gallon.

Two price series are used to estimate household fuel price, both come from EIA data. The first is an "official" estimate for the NHTS by the EIA (US EIA 2011b). This variable is called `GSCOST`. This variable uses data from a telephone survey of retail outlets and are published as Form EIA-878 for gasoline and Form EIA-888 for diesel. To be clear, these prices are sample and sales weighted averages of retail prices "at the pump," which includes taxes. The data is monthly and by state for gasoline and by PAD District and California for diesel fuel.

Taxes are calculated by the candidate and are subtracted from the gasoline price to create a new variable that is the price of gasoline exclusive of taxes. Federal taxes are 18.4 cents per gallon of gasoline and 24.4 cents per gallon of diesel in nominal dollars. As mentioned previously, these are all converted to 2010 dollars. State taxes are more complicated to calculate when they vary during the year. Some states regularly adjust their per gallon rate. Other states add an ad valorem sales tax to the cost of gasoline. In some states this sales tax is calculated prior to taxes and in others it is calculated on the price including taxes; therefore the data is needed for each state on how the tax is calculated. Complicating matters, it is necessary to weight the tax for estimates of consumption during the year. To do this correctly, and it appears that neither EIA or ORNL do when adjusting VMT, it is necessary to calculate weights to calculate the average during the twelve month prior to household's participation in the survey. The survey period lasted 14 months, therefore it is necessary to have price, tax, and fuel sales data for 26 months, including the 12 months prior to the first month of the survey. Sales volume data is obtained from the EIA and is available for most states. However, because of the number of weights that must be created (one set for each date, there are 30 survey dates when the 2001 NHTS is included), attempting to create a state specific weight for each state for each month exceeds the capabilities of the Microsoft Excel spreadsheet program. Therefore weights are created at the PAD District level. There are 12 weights (summing to 1) for each of the 12 months preceding the survey date for each of the PAD Districts. These are used to weight the state taxes, creating month specific average tax per gallon for each state in 2010 dollars.

Due to some of the data cleaning described above, there are some observations that are missing fuel prices in the baseline analysis. The weighted mean price for other observations with the same `CDIVMSAR` and `TDAYDATE` is used to complete those missing observations.

As an alternative to the official estimates, which rely on a limited and imperfect survey with a poorly documented methodology that produces some clearly unexpected results, there is a second price series from the EIA. The "Motor Gasoline Sales Though Retail Outlets Prices" (US EIA 2011c) data are collected from forms EIA-782A and EIA-782B, product sales reports from gasoline refiners and resellers, respectively. These prices exclude taxes and are perfectly sales weighted averages of all gasoline sales (of all grades) in each state in each month. The weighted methodology described above for the tax rates are applied to these prices to estimate an annual weighted average price of gasoline for each state and survey date. During the study period, there is one missing value for Arkansas and two missing values for Montana. These were estimated by taking the simple average of the month prior and the month following the missing value. The price series is missing for the District of Columbia during the study period. There are only 17 observations of retail gasoline price in the District of Columbia in the entire data set; the average of prices in Maryland and Virginia is a good predictor of those 17 observations. The missing retail gasoline prices for the District of Columbia are estimated by averaging the price in Maryland and the price in Virginia for the month of each missing value.

Normalize Sampling Weights

Twenty percent of the households in the 2001 NHTS and twelve percent of the households in the 2009 NHTS are dropped because they have incomplete data on household income, vehicle fuel economy, or vehicle VMT. The sampling weights must be adjusted because the households are not dropped randomly. Missing income data is assumed to be random, however.

The sampling weights are normalized by creating an 8x32 matrix of weighted population totals for each vehicle count group (0-7) in each geographic region (`CDIVMSAR`) for the entire sample in each survey year. Then create a 8x32 matrix of weighted population totals for each group after households with missing information have been dropped. Create a matrix of adjustment multipliers by dividing each value in the first matrix by the corresponding value in the second. The multiplier in groups with no dropped households equals 1. In all other groups the multiplier is > 1. Every sampling weight is multiplied by the multiplier for the group it is in.

CONSTRUCTION OF KEY VARIABLES

Dependent Variable: The natural log of estimated annual household VMT

Annual household VMT is simply the sum of the annual VMT of each household vehicle. There are two usable variables for annual vehicle VMT in the NHTS, both are obviously estimates of actual annual VMT and both are likely sources of bias. The first is a respondent estimate of the number of miles driven annually on each household vehicle. This variable is likely to be imprecise with the majority of responses being round, somewhat notional values.[68] The second is a "best estimate" created by researchers at ORNL using available data.

In the 2001 NHTS, two odometer readings were taken several months apart. These were annualized and adjusted for seasonality, characteristics of the primary driver, and characteristics of the household using a very complex regression methodology that includes the respondent estimate as an independent variable. Only half of households had two usable odometer readings; in those cases with missing odometer readings, the approach was used to predict VMT, but with the added step of adding *random residuals from the first half of the sample* to the predicted values. While this variable is quite precise, it is not clear that it is more accurate than the respondent estimates. In addition, this approach raises the concern that the ORNL VMT estimate is endogenous and

[68] For example, the five most common responses (10,000; 12,000; 2,500; 5,000; and 15,000) account for 31 percent of all observations and 33 percent of observations with a valid response.

unnecessarily random. Fortunately, ORNL does not consider price or income in their model, which is methodologically beneficial.

Only one odometer reading was taken for each vehicle in the 2009 NHTS. This means that there is no way to directly annualize VMT from two readings. Instead, ORNL estimates an initial annual mileage estimate for the regression using the single odometer reading and the age of the vehicle. As might be imagined, the methodology used to estimate annual was even more complex in 2009. To ensure that the estimates in 2009 were consistent with 2001, the 2001 data was used to produce the dependent variables for the regression for the 2009 estimates.

The ORNL approaches are as suspicious as they are difficult to describe. Therefore, while the ORNL estimate is the primary source of data for annual household VMT, both estimates are used to ensure that the results are insensitive to bias and error from the VMT estimates.

Household Average Price per-Mile

On road vehicle fuel economy and fuel price (including taxes) were estimated by the EIA (US EIA, 2011b). State fuel taxes were adopted from Table MF-205 from FHWA *Highway Statistics* (US FHWA 2010) and added to the data by the author. Local fuel taxes and sales taxes are not isolated. The retail fuel price includes all taxes.

Number and Type of Vehicles

The number of vehicles is capped at 8. Most households that have access to more than 6 vehicles do not have a significantly higher VMT than other households. This action improves the t-statistic for this variable and reduces the size of the residual for many households with more than 8 vehicles.

The dummy variable "*Multi*" is created equal to 1 for households with more than one vehicle where at least one vehicle if of a different type (`VEHTYPE`) than the others. All other households are set equal to 0.

The dummy variables *V2* and *V3* are set equal to 1 if the household has 2 or more than 2 vehicles. All equal 0 in households with 1 vehicle only and a household may only have one of these dummy variables set equal to 1. These are interacted with price instead of the natural log of the number of vehicles because the effect of multiple vehicles on the elasticity of demand with respect to price is non-parametric.

Household Type

Nine household type groups are created. Household types have 1 2 or more than 2 adults with 1, 2 or more than 2 vehicles. Table A.3 shows the proportion of households in each group where 8.6 percent of households have no vehicles, 32.3 percent of households have one vehicle, 36.3 percent of households have two vehicles, 14.4 percent of households have three vehicles and only 8.5 percent of households have four or more vehicles.

Table A.1 State Gasoline Excise Tax Rates in Cents per Gallon

State	2001	2002	2008	2009
Alabama	18.0	18.0	18.0	18.0
Alaska (1)	8.0	8.0	8.0	8.0
Arizona	18.0	18.0	18.0	18.0
Arkansas	19.5	21.7	21.5	21.5
California	18.0	18.0	18.0	18.0
Colorado	22.0	22.0	22.0	22.0
Connecticut	32.0	25.0	25.0	25.0
Delaware	23.0	23.0	23.0	23.0
District of Columbia	20.0	20.0	20.0	23.5
Florida	13.6	13.9	15.6	16.1
Georgia	7.5	7.5	7.5	7.5
Hawaii	16.0	16.0	17.0	17.0
Idaho	25.0	25.0	25.0	25.0
Illinois	19.0	19.0	19.0	19.0
Indiana	15.0	15.0	18.0	18.0
Iowa	20.0	20.1	21.0	21.0
Kansas	20.0	21.0	24.0	24.0
Kentucky	16.4	16.4	22.5	24.1
Louisiana	20.0	20.0	20.0	20.0
Maine	19.0	22.0	28.4	29.5
Maryland	23.5	23.5	23.5	23.5
Massachusetts	21.0	21.0	21.0	21.0
Michigan	19.0	19.0	19.0	19.0
Minnesota	20.0	20.0	22.5	27.1
Mississippi	18.4	18.4	18.4	18.4
Missouri	17.0	17.0	17.0	17.0
Montana	27.8	27.8	27.8	27.8
Nebraska	24.5	24.5	26.0	26.8
Nevada	24.0	24.0	24.0	24.0
New Hampshire	19.5	19.5	19.6	19.6
New Jersey	10.5	10.5	10.5	10.5
New Mexico	18.9	18.9	18.9	18.9
New York	22.1	22.7	24.5	25.2
North Carolina	24.3	24.2	30.2	30.2
North Dakota	21.0	21.0	23.0	23.0
Ohio	22.0	22.0	28.0	28.0
Oklahoma	17.0	17.0	17.0	17.0
Oregon	24.0	24.0	24.0	24.0
Pennsylvania	26.0	26.6	30.0	30.0
Rhode Island	29.0	29.0	30.0	30.0
South Carolina	16.0	16.0	16.0	16.0
South Dakota	22.0	22.0	22.0	22.0
Tennessee	20.0	20.0	20.0	20.0
Texas	20.0	20.0	20.0	20.0
Utah	24.5	24.5	24.5	24.5
Vermont	19.0	19.0	21.0	20.0
Virginia	17.5	17.5	17.5	17.5
Washington	23.0	23.0	37.5	37.5
West Virginia	25.4	25.7	32.2	32.2
Wisconsin	26.4	27.3	30.9	30.9
Wyoming	14.0	14.0	14.0	14.0

Note: (1) Alaska temporarily halted its fuel tax from September 2008 through August 2009.
Source: Table MF-205, "STATE MOTOR-FUEL TAX RATES, 1996 - 2009" from (US FHWA 2010).

Table A.2 State Diesel Excise Tax Rates in Cents per Gallon

State	2001	2002	2008	2009
Alabama	19.0	19.0	19.0	19.0
Alaska (1)	8.0	8.0	8.0	8.0
Arizona	27.0	26.0	26.0	26.0
Arkansas	20.5	22.7	22.5	22.5
California	18.0	18.0	18.0	18.0
Colorado	20.5	20.5	20.5	20.5
Connecticut	18.0	18.0	43.4	43.4
Delaware	22.0	22.0	22.0	22.0
District of Columbia	20.0	20.0	20.0	20.0
Florida	25.9	26.4	15.6	16.1
Georgia	7.5	7.5	7.5	7.5
Hawaii	16.0	16.0	17.0	17.0
Idaho	25.0	25.0	25.0	25.0
Illinois	21.5	21.5	21.5	21.5
Indiana	16.0	16.0	16.0	16.0
Iowa	22.5	22.5	22.5	22.5
Kansas	22.0	23.0	26.0	26.0
Kentucky	13.4	13.4	19.5	21.1
Louisiana	20.0	20.0	20.0	20.0
Maine	20.0	23.0	29.8	30.7
Maryland	24.25	24.25	24.25	24.25
Massachusetts	21.0	21.0	21.0	21.0
Michigan	15.0	15.0	15.0	15.0
Minnesota	20.0	20.0	20.0	27.1
Mississippi	18.4	18.4	18.4	18.4
Missouri	17.0	17.0	17.0	17.0
Montana	28.5	28.5	27.75	27.75
Nebraska	22.8	24.5	26.0	26.4
Nevada	27.0	27.0	27.0	27.0
New Hampshire	19.5	19.5	19.63	19.63
New Jersey	13.5	13.5	13.5	13.5
New Mexico	19.5	19.9	22.9	22.9
New York	20.25	20.85	22.65	23.35
North Carolina	24.3	24.2	30.15	30.15
North Dakota	21.0	21.0	23.0	23.0
Ohio	22.0	22.0	28.0	28.0
Oklahoma	14.0	14.0	14.0	14.0
Oregon	24.0	24.0	24.0	24.0
Pennsylvania	30.9	31.8	38.1	38.1
Rhode Island	29.0	29.0	30.0	30.0
South Carolina	16.0	16.0	16.0	16.0
South Dakota	22.0	22.0	22.0	22.0
Tennessee	17.0	17.0	17.0	17.0
Texas	20.0	20.0	20.0	20.0
Utah	24.5	24.5	24.5	24.5
Vermont	19.0	19.0	27.0	26.0
Virginia	16.0	16.0	17.5	17.5
Washington	23.0	23.0	37.5	37.5
West Virginia	25.35	25.65	32.2	32.2
Wisconsin	26.4	27.3	30.9	30.9
Wyoming	14.0	14.0	14.0	14.0

Note: (1) Alaska temporarily halted its fuel tax from September 2008 through August 2009.
Source: Table MF-205, "STATE MOTOR-FUEL TAX RATES, 1996 - 2009" from (US FHWA 2010).

Table A.3 Household Type Categories, 2009 NHTS

	One Adult	Two Adults	3 or More Adults
One Vehicle	20.6 percent	10.0 percent	1.7 percent
Two Vehicles	3.7 percent	29.0 percent	3.6 percent
3 or More Vehicles	1.2 percent	12.9 percent	8.8 percent
No vehicles (1)		8.6 percent	

Note: (1) Households with no vehicles are not disaggregated by household size.

Life Cycle Type

There are ten mutually exclusive lifecycle categories in the NHTS. However, it is convenient to condense these into just three categories: those with children, those comprised entirely of retired adults and all others.

CALCUALTING THE SUITS INDEX

Households are rank ordered by income and weighted by their share of accumulated income. The household's percent share of the accumulated tax burden is calculated.

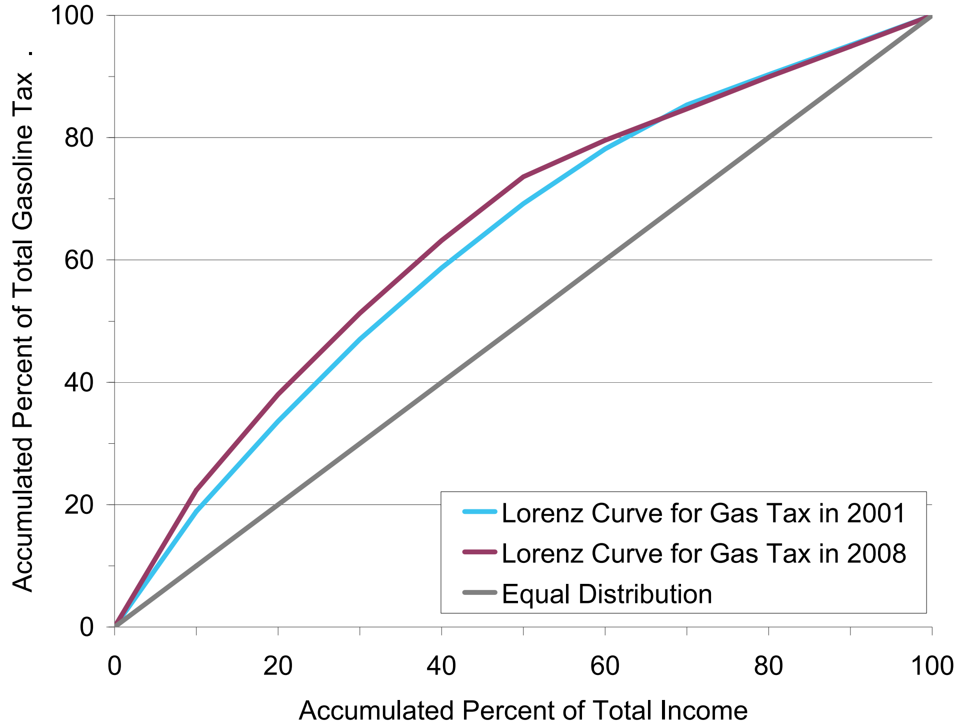
The area under the line of proportionality is 5000 (if using percent of the total, 50 otherwise). If we designate the area underneath the Lorenz curve for alternative VMT fee x, $\mathbf{L}_x$, then the Suits index can be expressed mathematically as

$$S_x = 1 - \frac{1}{5000}\int_0^{100} \mathrm{T}_x(y)dy = 1 - \frac{\mathrm{L}_x}{5000} \qquad (2)$$

where $\mathbf{T}_x(y)$ is the accumulated percent of the tax burden for one percent of accumulated income under alternative x.

Figure A.1 illustrates how the Suits index is calculated. The Lorenz curves based on the accumulated burden for the existing gasoline tax for each income decile, in the 2001 and 2009 NHTS, are shown in Figure A.1. These illustrate that the gasoline tax has become more regressive between the two surveys as the curve for the gasoline tax in the 2009 NHTS rise above the curve for the 2001 NHTS. The Suits indices confirm that the gasoline tax has become more regressive between 2008-09 and 2001-02 with the Suits index in 2008-09 being more negative than in 2001 at -0.3 to -0.26.

Figure A.1 Lorenz Curves for State and Federal Gasoline Tax, 2001-02 & 2008-09



CALCULATING THE CHANGE IN CONSUMER SURPLUS

The change in consumer welfare is calculated by evaluating the definite integral of the demand function in Equation 3.2 between the original price and the new price that is the result of each of the eight alternative tax policies. The demand function must be expressed as a function of price:

$$\int_{(p_f+t_0)}^{(p_f+t_1)} f(p)dp$$

In order to evaluate this expression, it is necessary to rewrite Equation 3.2 into two parts, a constant with respect to *p*, denoted as **A**, and a function of *p*, denoted as f(*p*).

$$\begin{aligned} \mathrm{A} = \alpha + \beta_2 \ln Y_i + \beta_3 \ln V_i + \beta_4 \ln Dist_i + \beta_5 \ln Density_i + \beta_6 W_i \\ + \beta_{MULTI} + \beta_{TRANSIT} + \beta_{HH\_TYPE} + \beta_{LIFECYCLE} + \beta_{STATE} \end{aligned} \tag{A.2}$$

$$\mathrm{f}(p) = \beta_1 \ln p_i + \beta_7 \ln p_i \cdot \ln Y_i + \beta_8 \ln p_i \cdot MPG_i + \beta_{V2} \ln p_i + \beta_{V3} \ln p_i \tag{A.3}$$

Now rewrite the demand function in terms of **A** and f(*p*):

$$\ln M = \mathrm{A} + \mathrm{f}(p) \tag{A.4}$$

Take the exponential of Equation A.4 to solve for *M*:

$$\begin{aligned} e(\ln M) &= e(\mathrm{A} + \mathrm{f}(p)) \\ M &= e^{\mathrm{A}} \cdot p^{\beta_1} \cdot p^{\beta_7 Y} \cdot p^{\beta_8 MPG} \cdot p^{\beta_{V2}} \cdot p^{\beta_{V3}} \end{aligned} \tag{A.5}$$

Equation A.5 can be simplified and rewritten as an expression of **A**, *p*, and the price elasticity of demand which will be denoted **B**:

$$\begin{aligned} M &= e^{\mathrm{A}} \cdot p^{\beta_1 + \beta_7 \ln Y + \beta_8 MPG + \beta_{V2} + \beta_{V3}} \\ M &= e^{\mathrm{A}} \cdot p^{\mathrm{B}} \end{aligned} \tag{A.6}$$

The change in consumer surplus from a change in the price of travel is the area underneath each household's demand function between the current price and the new price and is calculated by evaluating the definite integral of the demand function over the two prices. The simplified expression in Equation A.6 is easily integrated:

$$\begin{aligned} \Delta\mathrm{CS} &= \int_{(p_f+t_0)}^{(p_f+t_1)} f(p)dp \\ &= \int_{(p_f+t_0)}^{(p_f+t_1)} e^{\mathrm{A}} p^{\mathrm{B}} dp \\ &= e^{\mathrm{A}} \int_{(p_f+t_0)}^{(p_f+t_1)} p^{\mathrm{B}}\ dp \\ &= e^{\mathrm{A}} \frac{1}{\mathrm{B}+1} (p_f + t_0)^{\mathrm{B}+1} - e^{\mathrm{A}} \frac{1}{\mathrm{B}+1} (p_f + t_1)^{\mathrm{B}+1} \end{aligned}$$

$$\Delta\mathrm{CS} = \frac{e^{\mathrm{A}}}{\mathrm{B}+1} \left((p_f + t_0)^{\mathrm{B}+1} - (p_f + t_1)^{\mathrm{B}+1} \right) \tag{A.7}$$

where **B** is the price elasticity of demand.

Calculating the Change in Consumer Surplus Using an Alternative Price Elasticity

Once **A** is known, it is then possible to calculate the change in consumer surplus given any price elasticity. This allows the sensitivity of the results to the assumption that the elasticity varies with household income and the number of vehicles to be easily tested. In the dissertation, the results are tested using an elasticity of -0.22, which is culled from a review of other research as a consensus best estimate of the long-run price elasticity of demand for VMT, and -1.[69] This is realized in Equations A.8 and A.9:

$$\Delta \text{CS} = \frac{e^{\text{A}}}{0.78}\left((p_f + t_0)^{0.78} - (p_f + t_1)^{0.78} \right) \tag{A.8}$$

$$\Delta \text{CS} = \frac{e^{\text{A}}}{0.000001}\left((p_f + t_0)^{0.000001} - (p_f + t_1)^{0.000001} \right) \tag{A.9}$$

CALCULATING THE NET CHANGE IN HOUSEHOLD WELFARE

The net change in household welfare is calculated by adding to the change in consumer surplus (zero in households without vehicles) the household's share of the social values of the net change in revenue and the net change in the external costs of pollution, accidents, congestion, and GHG emissions. This is illustrated in Equation A.10:

$$\Delta \text{Welfare} = \Delta \text{CS} + \Delta \text{Revenue} - \Delta \text{Externalities} \tag{A.10}$$

Changes in revenue and externalities are calculated at the household level from national (and state-level) changes in VMT and fuel consumption given the tax rates and the values of travel related externalities. As explained in Section 3, there are two alternative methods of revenue recycling used which result in two different welfare calculations:

Method 1: lump sum revenue recycling

$$\begin{aligned}
\Delta \text{Revenue} = & \left(\sum_{i=1}^{N} (\text{Federal MBUF Rate} \cdot \text{VMT}_i) - \text{Total Federal MBUF Collection Cost} \right) \\
& - \left(\sum_{i=1}^{N} (18.4 \cdot \text{Gallons}_i) - \text{Total Federal Fuel Tax Collection Cost} \right) \\
& + \sum_{s=1}^{51} \left(\sum_{i=1}^{N} (\text{State MBUF Rate}_S \cdot \text{VMT}_{i,S}) - \text{Total State MBUF Collection Cost}_S \right) \\
& - \sum_{s=1}^{51} \left(\sum_{i=1}^{N} (\text{State Fuel Tax Rate}_S \cdot \text{Gallons}_{i,S}) - \text{Total State Fuel Tax Collection Cost}_S \right)
\end{aligned}$$

$$\Delta \text{Revenue}_{\text{per person}} = \Delta \text{Revenue} / \text{Total Population}$$

$$\Delta \text{Revenue}_i = \Delta \text{Revenue}_{\text{per person}} \cdot n_i$$

for household i in state S. Where N is the number of weighted households and n_i is the number of people residing in household i. Repeat for each alternative (including new fuel tax rates).

[69] Careful readers will note that using -1 is not possible mathematically. -0.99999 is used instead which approximates unit elasticity.

Method 2: mixed revenue recycling

$$\begin{aligned}
\Delta\text{Revenue} = & \left(\sum_{i=1}^{N} \left(\text{Federal MBUF Rate} \cdot \text{VMT}_i \right) - \text{Total Federal MBUF Collection Cost} \right) \\
& - \left(\sum_{i=1}^{N} \left(18.4 \cdot \text{Gallons}_i \right) - \text{Total Federal Fuel Tax Collection Cost} \right) \\
& + \sum_{s=1}^{51} \left(\sum_{i=1}^{N} \left(\text{State MBUF Rate}_S \cdot \text{VMT}_{i,S} \right) - \text{Total State MBUF Collection Cost}_S \right) \\
& - \sum_{s=1}^{51} \left(\sum_{i=1}^{N} \left(\text{State Fuel Tax Rate}_S \cdot \text{Gallons}_{i,S} \right) - \text{Total State Fuel Tax Collection Cost}_S \right)
\end{aligned}$$

$$\Delta\text{Revenue}_{\text{per person}} = \Delta\text{Revenue/Total Population}$$

$$\Delta\text{Revenue}_i = \left(\left(\Delta\text{Revenue}_{\text{per person}} \cdot n_i \right) / 2 \right) + \left(\left(\Delta\text{Revenue/Total VMT/2} \right) \cdot \text{VMT}_i \right)$$

This is simplified. The program calculates state VMT separately.

B. ADDITIONAL TABLES

PROJECTIONS OF CHANGES IN CONSUMER SURPLUS FOR KEY GROUPS IN ALL SCENARIOS

Table B.1 Projections of Changes in Group Consumer Surplus, Reference Case, 2015 - 2030

	Flat MBUF, Federal				Add 1 Cent MBUF				Tiered MBUF			
	2015	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**
Population Average	-5.88	-14.09	-19.68	-22.01	-147.99	-132.32	-121.08	-110.29	-120.01	-115.99	-112.72	-106.60
Population Thirds												
Low Income	-2.07	-5.97	-8.70	-9.91	-67.37	-60.57	-55.91	-51.31	-43.38	-43.01	-42.72	-41.02
Middle Income	-5.08	-13.37	-19.05	-21.47	-146.62	-131.23	-120.27	-109.70	-116.70	-113.11	-110.24	-104.49
High Income	-10.49	-22.93	-31.30	-34.66	-229.97	-205.16	-187.06	-169.85	-199.93	-191.83	-185.18	-174.29
Household Life Cycle												
Household with children	-9.01	-20.47	-28.24	-31.42	-209.44	-187.09	-170.96	-155.51	-187.14	-179.48	-173.38	-163.35
Retired household	-1.14	-6.11	-9.53	-11.06	-82.50	-73.89	-67.80	-61.90	-58.51	-57.38	-56.40	-53.74
Other households	-6.36	-13.87	-19.00	-21.11	-137.90	-123.37	-112.99	-102.99	-101.95	-99.23	-96.92	-91.96
Community Type												
Urban	-6.25	-10.81	-13.93	-15.13	-90.32	-80.85	-74.14	-67.66	-55.88	-55.15	-54.45	-52.01
Second City	-6.85	-13.35	-17.79	-19.57	-123.18	-110.22	-100.98	-92.07	-85.94	-83.99	-82.31	-78.26
Suburb	-9.19	-17.06	-22.41	-24.50	-152.03	-135.90	-124.31	-113.18	-111.13	-108.04	-105.41	-99.90
Rural	-3.29	-14.06	-21.41	-24.62	-182.04	-162.71	-148.80	-135.46	-168.92	-161.95	-156.45	-147.42

Table B.2 Projections of Changes in Group Consumer Surplus, High Economic Growth Case, 2015 - 2030

	Flat MBUF, Federal				Add 1 Cent MBUF				Tiered MBUF			
	2015	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**
Population Average	-6.20	-15.27	-21.54	-24.79	-151.53	-140.30	-130.70	-122.60	-123.09	-123.42	-122.17	-118.97
Population Thirds												
Low Income	-2.20	-6.44	-9.43	-11.07	-68.88	-63.85	-59.76	-56.55	-44.46	-45.58	-45.96	-45.48
Middle Income	-5.38	-14.48	-20.81	-24.14	-150.09	-139.00	-129.59	-121.76	-119.66	-120.25	-119.29	-116.44
High Income	-11.03	-24.88	-34.39	-39.16	-235.62	-218.04	-202.73	-189.47	-205.13	-204.43	-201.25	-194.98
Household Life Cycle												
Household with children	-9.48	-22.20	-30.96	-35.44	-214.51	-198.57	-184.83	-173.12	-191.93	-191.00	-187.98	-182.36
Retired household	-1.27	-6.65	-10.42	-12.45	-84.44	-78.20	-72.96	-68.62	-60.01	-61.02	-61.04	-59.89
Other households	-6.67	-14.99	-20.75	-23.74	-141.18	-130.73	-121.84	-114.39	-104.58	-105.61	-105.05	-102.62
Community Type												
Urban	-6.50	-11.64	-15.18	-16.98	-92.45	-85.60	-79.83	-75.05	-57.33	-58.68	-58.96	-57.99
Second City	-7.16	-14.41	-19.42	-21.99	-126.11	-116.78	-108.85	-102.23	-88.15	-89.38	-89.18	-87.30
Suburb	-9.58	-18.42	-24.50	-27.56	-155.69	-144.13	-134.24	-125.87	-114.01	-115.05	-114.36	-111.59
Rural	-3.59	-15.33	-23.50	-27.80	-186.42	-172.60	-160.74	-150.67	-173.23	-172.30	-169.54	-164.50

Table B.3 Projections of Changes in Group Consumer Surplus, Low Economic Growth Case, 2015 - 2030

	Flat MBUF, Federal				Add 1 Cent MBUF				Tiered MBUF			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
Population Average	-5.72	-13.21	-17.92	-19.78	-145.29	-126.42	-111.87	-100.18	-117.72	-110.48	-103.83	-96.49
Population Thirds												
Low Income	-2.02	-5.61	-7.94	-8.98	-66.28	-58.12	-51.87	-47.02	-42.62	-41.09	-39.47	-37.38
Middle Income	-4.94	-12.54	-17.36	-19.33	-144.00	-125.48	-111.21	-99.80	-114.51	-107.82	-101.62	-94.71
High Income	-10.21	-21.48	-28.47	-31.04	-225.59	-195.66	-172.54	-153.71	-196.02	-182.53	-170.39	-157.36
Household Life Cycle												
Household with children	-8.77	-19.19	-25.71	-28.20	-205.55	-178.62	-157.84	-141.05	-183.57	-170.95	-159.70	-147.80
Retired household	-1.09	-5.70	-8.66	-9.95	-81.05	-70.69	-62.72	-56.38	-57.41	-54.68	-51.98	-48.71
Other households	-6.19	-13.03	-17.32	-19.01	-135.41	-117.92	-104.44	-93.63	-100.01	-94.50	-89.27	-83.23
Community Type												
Urban	-6.10	-10.19	-12.73	-13.65	-88.72	-77.33	-68.57	-61.60	-54.83	-52.54	-50.17	-47.12
Second City	-6.68	-12.56	-16.23	-17.63	-120.97	-105.37	-93.35	-83.73	-84.30	-80.00	-75.83	-70.86
Suburb	-8.96	-16.05	-20.44	-22.03	-149.25	-129.82	-114.83	-102.77	-108.99	-102.86	-97.05	-90.35
Rural	-3.15	-13.11	-19.44	-22.09	-178.70	-155.41	-137.44	-122.96	-165.71	-154.30	-144.14	-133.45

Table B.4 Projections of Changes in Group Consumer Surplus, High Oil Price Case, 2015 - 2030

	Flat MBUF, Federal				Add 1 Cent MBUF				Tiered MBUF			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
Population Average	-6.23	-14.31	-19.71	-22.09	-135.95	-120.26	-109.33	-99.59	-112.65	-108.55	-105.22	-99.83
Population Thirds												
Low Income	-2.11	-5.65	-8.10	-9.26	-58.16	-51.19	-46.91	-43.12	-39.04	-38.26	-37.86	-36.50
Middle Income	-5.33	-13.38	-18.80	-21.25	-133.13	-117.66	-107.13	-97.76	-108.37	-104.55	-101.64	-96.68
High Income	-11.24	-23.89	-32.22	-35.74	-216.55	-191.93	-173.93	-157.88	-190.53	-182.85	-176.17	-166.32
Household Life Cycle												
Household with children	-9.60	-21.03	-28.62	-31.89	-194.30	-172.01	-156.17	-142.06	-175.88	-168.28	-162.20	-153.31
Retired household	-1.47	-6.26	-9.48	-11.00	-74.34	-65.67	-59.84	-54.66	-54.48	-53.16	-52.10	-49.81
Other households	-6.48	-13.83	-18.75	-20.91	-125.95	-111.38	-101.32	-92.37	-95.82	-92.97	-90.56	-86.18
Community Type												
Urban	-6.13	-10.52	-13.47	-14.70	-81.61	-72.09	-65.66	-59.94	-52.19	-51.29	-50.49	-48.39
Second City	-6.91	-13.24	-17.48	-19.30	-112.23	-99.22	-90.29	-82.34	-80.55	-78.46	-76.68	-73.14
Suburb	-9.26	-17.05	-22.23	-24.40	-140.04	-123.91	-112.60	-102.53	-104.95	-101.83	-99.10	-94.23
Rural	-4.12	-14.80	-21.92	-25.18	-168.01	-148.69	-135.10	-122.99	-158.35	-151.36	-145.85	-137.87

Table B.5 Projections of Changes in Group Consumer Surplus, Low Oil Price Case, 2015 - 2030

	Flat MBUF, Federal				Add 1 Cent MBUF				Tiered MBUF			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
Population Average	-6.03	-15.09	-20.35	-22.32	-162.91	-146.42	-137.09	-123.63	-129.13	-125.40	-122.60	-114.53
Population Thirds												
Low Income	-2.30	-6.96	-9.99	-11.09	-79.82	-72.50	-70.17	-63.38	-49.04	-49.16	-49.98	-47.23
Middle Income	-5.35	-14.62	-20.12	-22.18	-163.45	-147.17	-138.51	-124.94	-127.09	-123.87	-121.87	-113.97
High Income	-10.45	-23.71	-30.94	-33.69	-245.43	-219.60	-202.58	-182.54	-211.25	-203.17	-195.93	-182.38
Household Life Cycle												
Household with children	-9.07	-21.56	-28.62	-31.28	-227.68	-204.26	-190.08	-171.36	-201.05	-193.53	-187.92	-174.90
Retired household	-1.04	-6.65	-10.02	-11.41	-92.95	-83.82	-79.33	-71.57	-63.57	-62.78	-62.30	-58.58
Other households	-6.75	-15.11	-20.06	-21.81	-152.91	-137.59	-129.29	-116.62	-109.57	-107.23	-105.35	-98.74
Community Type												
Urban	-6.73	-11.91	-15.04	-15.98	-101.48	-91.45	-86.42	-77.95	-60.57	-60.21	-59.94	-56.50
Second City	-7.24	-14.53	-18.84	-20.29	-137.01	-123.33	-116.04	-104.67	-92.68	-91.13	-89.91	-84.41
Suburb	-9.67	-18.35	-23.36	-25.02	-166.80	-149.85	-140.07	-126.31	-118.73	-115.98	-113.51	-106.31
Rural	-2.97	-14.78	-21.54	-24.38	-199.18	-178.89	-167.01	-150.60	-181.99	-175.21	-170.37	-158.58

Table B.6 Projections of Changes in Group Consumer Surplus, Extend Policies Case, 2015 - 2030

	Flat MBUF, Federal				Add 1 Cent MBUF				Tiered MBUF			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
Population Average	-5.93	-16.36	-30.01	-36.09	-147.78	-133.25	-125.34	-116.87	-119.93	-118.80	-125.49	-124.50
Population Thirds												
Low Income	-2.09	-7.07	-13.93	-17.32	-67.20	-61.35	-59.59	-56.93	-43.32	-44.44	-49.51	-50.81
Middle Income	-5.13	-15.66	-29.53	-35.85	-146.38	-132.29	-125.14	-117.16	-116.60	-116.02	-123.53	-123.20
High Income	-10.57	-26.36	-46.57	-55.11	-229.75	-206.10	-191.30	-176.51	-199.85	-195.93	-203.42	-199.48
Household Life Cycle												
Household with children	-9.08	-23.65	-42.55	-50.79	-209.18	-188.22	-176.10	-163.50	-187.02	-183.48	-191.43	-188.58
Retired household	-1.17	-7.42	-15.57	-19.40	-82.35	-74.54	-70.83	-66.55	-58.46	-59.00	-63.88	-64.29
Other households	-6.40	-16.00	-28.71	-34.41	-137.69	-124.30	-117.30	-109.65	-101.89	-101.79	-108.60	-108.33
Community Type												
Urban	-6.27	-12.19	-20.28	-23.90	-90.16	-81.55	-77.36	-72.60	-55.85	-56.79	-61.96	-62.58
Second City	-6.88	-15.24	-26.42	-31.41	-122.99	-111.08	-104.95	-98.20	-85.88	-86.26	-92.68	-92.82
Suburb	-9.23	-19.36	-32.82	-38.68	-151.83	-136.82	-128.51	-119.68	-111.07	-110.76	-117.73	-117.10
Rural	-3.35	-16.89	-34.20	-41.99	-181.80	-163.78	-153.68	-143.01	-168.80	-165.59	-172.89	-170.48

Table B.7 Projections of Changes in Group Consumer Surplus, Six Percent Growth in CAFE Standards Case, 2015 - 2030

	Flat MBUF, Federal				Add 1 Cent MBUF				Tiered MBUF			
	2015	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**	**2015**	**2020**	**2025**	**2030**
Population Average	-5.99	-17.71	-35.00	-44.61	-147.79	-133.68	-127.21	-120.92	-119.99	-120.39	-131.52	-135.25
Population Thirds												
Low Income	-2.12	-7.72	-16.53	-22.13	-67.20	-61.72	-61.23	-60.59	-43.35	-45.25	-52.79	-57.08
Middle Income	-5.19	-17.01	-34.62	-44.65	-146.39	-132.78	-127.27	-121.78	-116.66	-117.66	-129.81	-134.55
High Income	-10.66	-28.39	-53.84	-67.05	-229.76	-206.53	-193.13	-180.39	-199.95	-198.26	-211.96	-214.10
Household Life Cycle												
Household with children	-9.17	-25.53	-49.42	-62.33	-209.19	-188.74	-178.34	-168.32	-187.10	-185.74	-199.91	-203.56
Retired household	-1.20	-8.19	-18.52	-24.56	-82.36	-74.85	-72.17	-69.49	-58.50	-59.92	-67.44	-70.76
Other households	-6.45	-17.25	-33.41	-42.51	-137.69	-124.74	-119.20	-113.79	-101.95	-103.24	-114.14	-118.22
Community Type												
Urban	-6.30	-13.00	-23.37	-29.33	-90.16	-81.87	-78.78	-75.71	-55.88	-57.72	-65.55	-69.06
Second City	-6.93	-16.35	-30.60	-38.66	-122.99	-111.48	-106.71	-102.02	-85.93	-87.55	-97.61	-101.65
Suburb	-9.29	-20.71	-37.83	-47.22	-151.83	-137.24	-130.35	-123.67	-111.13	-112.31	-123.56	-127.37
Rural	-3.43	-18.56	-40.37	-52.42	-181.81	-164.27	-155.82	-147.63	-168.88	-167.63	-180.63	-184.25

Table B.8 Projections of Changes in Group Consumer Surplus, Skew Distribution Case, 2015 - 2030

	Flat MBUF, Federal				Add 1 Cent MBUF				Tiered MBUF			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
Population Average	-11.06	-19.67	-25.61	-27.77	-150.05	-135.09	-124.57	-114.10	-124.38	-119.53	-115.54	-108.65
Population Thirds												
Low Income	-4.56	-8.88	-12.11	-13.51	-69.09	-62.93	-58.96	-54.73	-44.84	-43.70	-42.87	-40.75
Middle Income	-10.04	-18.67	-24.71	-27.02	-148.98	-134.41	-124.27	-114.07	-120.67	-115.96	-112.18	-105.60
High Income	-18.59	-31.46	-39.99	-42.78	-232.07	-207.94	-190.46	-173.48	-207.63	-198.93	-191.57	-179.60
Household Life Cycle												
Household with children	-16.43	-28.41	-36.50	-39.30	-211.89	-190.32	-174.93	-159.79	-194.07	-185.64	-178.78	-167.71
Retired household	-3.51	-8.38	-11.80	-13.21	-83.74	-75.47	-69.76	-64.03	-60.14	-58.00	-56.24	-53.01
Other households	-11.47	-19.62	-25.35	-27.47	-140.18	-126.56	-117.09	-107.55	-105.92	-102.44	-99.50	-93.85
Community Type												
Urban	-10.16	-15.59	-19.45	-20.83	-92.13	-83.43	-77.50	-71.40	-58.92	-58.07	-57.23	-54.45
Second City	-11.78	-19.12	-24.25	-26.09	-125.30	-113.17	-104.77	-96.26	-89.97	-87.70	-85.69	-81.11
Suburb	-15.35	-24.24	-30.37	-32.44	-154.37	-139.18	-128.49	-117.79	-116.50	-113.31	-110.46	-104.38
Rural	-8.53	-18.93	-26.03	-28.74	-184.02	-165.18	-151.78	-138.65	-173.43	-164.66	-157.69	-147.46

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