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Equity in User-Fee Systems: Accounting for Locational Differences in Travel Demand

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Abstract

User fees are an alternative source of revenue to fuel taxes. Unfortunately, public perception of inequity in user-fee systems complicates program implementation. The need for new sources of revenue to fund transportation in the United States means empirical research to explore the equity of user-fee systems is important. One version of equity of import to the public is the fairness of a fee for users in rural locations where travel demand is greater than in urban locations. The potential difference in the fees rural users incur versus the fees urban users incur due to differences in travel demand is the focus of the study. Specifically, the study answers a call in the equity literature to use disaggregated data to explore how locational differences in travel demand could impact user-fee systems. Adoption of a multilevel approach nests vehicles within households to estimate the magnitude of the rural–urban difference in travel demand. Analysis of a user-fee program in the State of Oregon provides modest empirical evidence for locational differences in travel demand. In terms of vehicle kilometers of travel (VKT), the rural–urban difference is only +14.44 kilometers. Results from a subsequent series of price scenarios show how to adjust a user-fee system to account for the modest rural–urban difference in VKT. Overall, results from the study suggest public perceptions of rural–urban differences in travel demand are not entirely without merit. However, adjustment of programs to implement user-fee systems could help solve modest inequity problems due to rural–urban differences in travel demand.

Keywords: user-fee system, equity, travel demand, fuel economy, geographic location

Équité dans les systèmes de tarification : prise en compte des différences géographiques dans la demande de déplacements

Résumé

Les frais d'utilisation sont une autre source de revenus que les taxes sur les carburants. Malheureusement, la perception publique de l'iniquité dans les systèmes de tarification complique la mise en œuvre du programme. Le besoin de nouvelles sources de revenus pour financer le transport aux États-Unis signifie que la recherche empirique pour explorer l'équité des systèmes de frais d'utilisation est importante. Une version de l'équité de l'importation pour le public est l'équité d'une redevance pour les utilisateurs dans les zones rurales où la demande de déplacement est plus élevée que dans les zones urbaines. La différence potentielle dans les frais encourus par les utilisateurs ruraux par rapport aux frais encourus par les utilisateurs urbains en raison des différences dans la demande de déplacement est au centre de l'étude. Plus précisément, l'étude répond à un appel dans la littérature sur l'équité à utiliser des données désagrégées pour explorer comment les différences de localisation dans la demande de déplacements pourraient avoir un impact sur les systèmes de tarification. L'adoption d'une approche à plusieurs niveaux imbrique les véhicules dans les ménages pour estimer l'ampleur de la différence rurale-urbaine dans la demande de déplacement. L'analyse d'un programme de frais d'utilisation dans l'État de l'Oregon fournit des preuves empiriques modestes des différences d'emplacement dans la demande de déplacements. En termes de véhicules-kilomètres parcourus (VKT), l'écart rural-urbain n'est que de +14,44 kilomètres. Les résultats d'une série ultérieure de scénarios de prix montrent comment ajuster un système de frais d'utilisation pour tenir compte de la modeste différence rurale-urbaine dans le VKT. Dans l'ensemble, les résultats de l'étude suggèrent que les perceptions du public à l'égard des différences rurales-urbaines dans la demande de déplacement ne sont pas entièrement sans fondement. Cependant, l'ajustement des programmes pour mettre en œuvre des systèmes de frais d'utilisation pourrait aider à résoudre les problèmes d'inégalité modestes dus aux différences entre les zones rurales et urbaines dans la demande de déplacements.

Mots-clés : système de frais d'utilisation, équité, demande de déplacements, économie de carburant, emplacement géographique

1.0 Introduction

The need for a new revenue source for the Highway Trust Fund is well known. The National Surface Transportation Infrastructure Financing Commission (2009) set up by the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users of 2005 recommends a ten-cent increase in the federal excise tax on gasoline to increase the present revenue source and a user-fee system as a future revenue source. On the one hand, the political will to increase the federal excise tax on gasoline from 18.4 cents per gallon is nonexistent (Schank & Rudnick-Thorpe, 2011). On the other hand, the Fixing America's Surface Transportation Act of 2015 allocated a total of $95 million from fiscal year 2016 to fiscal year 2020 to set up the Surface Transportation System Funding Alternatives (STSFA) Program. STSFA provides grants to states or to groups of states to test user-fee systems as a new revenue source for the Highway Trust Fund.

In order to better understand how a transition to a user-fee system could differentially affect drivers as a function of geographic location (National Surface Transportation Infrastructure Financing Commission, 2009), the study analyzes household data on travel demand for an entire state. The research questions the study attempts to answer are as follows. First, what is the rural–urban difference in travel demand in terms of vehicle kilometers of travel (VKT)? The first question is important to establish if perceptions match reality with regard to differences in travel demand for rural users versus urban users. Second, what is the magnitude of the effect of fuel economy on travel demand for different households across the state? The second question is important because the demand increases attributable to fuel economy could unfairly burden drivers from rural households after program implementation. Third, how could differences in the effect of fuel economy impact equity in a statewide user-fee system? The third question is important because, on the one hand, the magnitude of the effect of fuel economy is ultimately dependent on travel demand at the household, or the micro, level which is the most disaggregated level of analysis. On the other hand, any rural inequity is dependent on the classification of locations at the regional, or the macro, level (Primo et al., 2007). To that end, any locational inequity is dependent on the aggregation of households into classes—rural versus urban—known to be a challenge to codify, especially in the State of Oregon (Crandall & Weber, 2005).

The organization of the study is as follows. The background section reviews the empirical literature on the rural–urban divide in user-fee systems, the travel demand-inducing effect of fuel economy, and the first user-fee system in the United States in the State of Oregon known as OReGO. The methodology section describes the rationale, the model, and the data to estimate the rural–urban difference in VKT and to estimate the magnitude of the effect of fuel economy on VKT in rural locations versus urban locations. The methodology section also hypothesizes on the effects of the independent variables at the vehicle level, the household level, and the county level of the models, respectively. The results section presents the model results and the scenario results. The discussion section highlights the implications of the results on user-fee systems for different drivers. Finally, the conclusions section highlights the contributions of the models and the scenarios to the empirical literature as well as the most fruitful direction for future research on user-fee systems.

2.0 Background

2.1 Rural–Urban Divide

The flexibility of user-fee systems (Forkenbrock, 2008) means drivers can ultimately pay for what they get (Bird, 1976) regardless of geographic location. However, empirical evidence, thus far, is inconsistent with public perception of a rural inequity in user-fee systems. It is important, then, to better understand how such systems could differentially affect drivers. For example, one disadvantage of a user-fee system is the shift in revenue burden to drivers who travel more in distance (Schank & Rudnick-Thorpe, 2011). Such a shift is problematic from an equity perspective because of the divide between rural drivers versus urban drivers in travel demand. Indeed, vehicle kilometers of travel (VKT) per day are much higher for rural drivers (55.0) than urban drivers (37.2) (Santos et al., 2011). Not surprisingly, one of the issues STSFA grant recipients can test is the relative burden of user fees on rural drivers versus urban drivers.

An estimate of the statewide distributional impact of a flat, 1.2 cent-per-mile fuel tax in the State of Oregon by Zhang et al. (2009) shows that, in the short run, the total change in consumer surplus[1] should be greater for rural households (+$9.42 million) than urban households (+$2.05 million). Zhang et al. (2009) attribute the greater short-run consumer surplus for rural households to the fact that rural households own a higher percentage of vehicle types of lower fuel economy such as SUVs. However, in the long run, the total change in consumer surplus should be less for rural households (−$2.29 million) than urban households (+$5.43 million). Zhang et al. (2009) attribute the difference in consumer surplus from the short-run to the long-run to the fact that rural households are less flexible in the number of vehicles they own and the type of vehicles they own. Owning a greater number of vehicles and owning vehicle types of lower fuel economy probably contributes to the change in the consumer surplus for rural households from the short-run to the long-run. An assessment of the distributional impacts of a transition from a fuel tax to a user fee in the State of Oregon (McMullen et al., 2010) shows that rural households should benefit from the latter relative to urban households. An analysis of the effectiveness and the equity of user fees at the federal level and the state level by Robitaille et al. (2011) also shows that rural households could benefit from a fuel-tax-to-user-fee transition. A nationwide study of the distributional implications of a transition from a fuel tax to a user fee (Weatherford, 2011) shows that the latter could shift the burden from rural users to urban users. In a scenario where users of rural roads and users of urban roads incur different fees, Larsen et al. (2012) found that a rural-versus-urban fee scenario disadvantages the poor the most (Litman, 2002). A comparison of the effects of an increase in the federal fuel tax and the state fuel tax versus a user fee by Kastrouni et al. (2015) shows that both revenue sources could adversely affect rural households. In the fuel-tax case, an analysis of data for the United States by Kastrouni et al. (2015) shows that rural households operate lower fuel-economy vehicles and generate more trips annually, so they are vulnerable in both revenue scenarios. In the user-fee case, an analysis of data from the State of Iowa also by Kastrouni et al. (2015) shows that vehicle miles of travel are higher for rural households so they could incur higher fees after implementation

[1] Consumer surplus is the monetary gain if the price consumers pay for a good or a service is less than the highest price consumers are willing to pay for a good or a service.

of a user-fee program. Finally, an analysis of the statewide economic impact of a user-fee system in the State of Oregon shows that costs for households could increase by five cents per day on average (McMullen et al., 2016b).

2.2 Travel Demand-Inducing Effect of Better Fuel Economy

Blair et al. (1984) and Crandall (1992) highlight the travel demand-inducing effect of better fuel economy via a reduction in the marginal cost of travel. In the context of the present study, the magnitude of the effect of better fuel economy on travel demand is highly relevant given the upward trend in fleet fuel economy across the United States over the time period of the data from 2009 to 2011 (Environmental Protection Agency, 2014). Research on the travel demand-inducing effect of better fuel economy on user-fee systems is not extensive.[2] In a study on differences in the regional determinants of travel demand across the State of Oregon, Ke and McMullen (2017) found that, contrary to expectations, households that own electric vehicles which are not fuel dependent at all or hybrid vehicles which are less fuel dependent drove less. However, rural households drove more. Likewise, there are significant regional determinants of travel demand that could differentially impact households after the implementation of a statewide user-fee program. Further, Kastrouni et al. (2015) call for future research to use disaggregated data on travel demand in order to explore differential impacts within households. The latter is the impetus for the present empirical study.

2.3 OReGO

Oregon was the first state to enact a fuel tax[3] as a revenue source (Jones & Bock, 2017). Fittingly, Oregon is the first state to implement a user-fee program. The enactment of Senate Bill 810 by the Oregon Legislature in 2013 and the launch of OReGO by the Oregon Department of Transportation (ODOT) in 2015 solves a problem with a user-pays policy to fund transportation. A user-pays policy to fund transportation links usage to costs. But because the present vehicle fleet has better fuel economy and is less dependent on fuel than the past vehicle fleet the linkage between fuel consumption and road usage is weak. A user-fee system relinks usage to costs regardless of the vehicle fleet because user charges are proportional to usage. To that end, OReGO strengthens a user-pays policy to fund transportation.

The maximum number of vehicles in OReGO set by Senate Bill 810 is 5,000 to minimize costs. The cap on the number of vehicles with a fuel economy of less than 17 miles per gallon is 1,500. The cap on the number of vehicles with a fuel economy between 17 miles per gallon and 22 miles per gallon is 1,500. Senate Bill 810 sets no cap on the number of vehicles with a fuel economy greater than 22 miles per gallon. By 2017, vehicle enrollment was 1,307 with 669 active vehicles. Volunteer enrollment was 1,111 with 800 active volunteers. The vehicles in OReGO are of 40 makes and about 300 models from model year 1996 to 2017. The Toyota Prius and the Ford F-150 are the most frequent makes–models. OReGO is revenue neutral to a 30-cent fuel tax for a vehicle with a fuel economy of 20 miles per gallon. The latter is the most frequent fuel economy in the vehicle fleet at the time of launch. Drivers

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[2] Research on the adjustments households would make to the fuel economy of their private vehicles after implementation of a user-fee program is ongoing (Small & Van Dender, 2007).

[3] The tax rate in 1919 was one cent per gallon (Oregon Department of Transportation, 2018). The tax rate in 2022 is 38 cents per gallon (Oregon Department of Transportation, 2022).

pay a flat, 1.5 cent-per-mile fee regardless of geographic location, vehicle type, or fuel economy.[4] The goal is for the program to be mandatory for all new vehicles in the State of Oregon by 2026.

ODOT is one of the STSFA grant recipients to improve OReGO. To that end, the opinions of OReGO volunteers are important to acknowledge. For example, surveys of OReGO volunteers (Jones & Bock, 2017) reveal public perception of unfairness toward rural drivers, low-income drivers, and drivers of vehicles with better fuel economy. To put the opinions of OReGO volunteers into context, a synthesis of 110 focus groups and surveys by Zmud and Arce (2008) shows that the majority (56%) are supportive of charges for road use. However, opposition increases with public perception of unfairness. Therefore, research on differences in vehicle usage and travel demand across the rural–urban divide is important to ensure user-fee program implementation is fair.

3.0 Methodology

3.1 Rationale

According to Ke and McMullen (2017) there are significant regional differences in the determinants of household travel demand across the State of Oregon. What is not yet evident from the empirical literature is how much of the variation in travel demand is attributable to the characteristics of the vehicles driven by household members such as their fuel economy, how much is attributable to the characteristics of the household such as income, and how much is attributable to the location of the household.

The advantages of a multilevel model of travel demand are as follows (Snijders & Bosker, 1999). First, a multilevel model explicitly nests vehicles within households within counties across the State of Oregon because the dependent variable (VKT) consists of a vehicle level, a household level, and a county level. The levels summarize the average vehicle–household–county relationship across the State of Oregon as well as the variation in the vehicle–household–county relationship across the State of Oregon (Duncan & Jones, 2000). In contrast, the average vehicle–household–county relationship in a multiple regression model is fixed so only one relationship between vehicles, households, and counties across the State of Oregon is allowed. Second, because all of the observations are assumed to be independent (Bullen et al., 1997), only one variance term summarizes the random part of a multiple regression model. This assumption could prove to be untenable if the grouping of observations into different classes yields similar error terms which vary systematically by county (Moulton, 1990). On the other hand, error terms at each level extend the random part of a multilevel model (Primo et al., 2007).

3.2 Models

The models in the study nest vehicles (*v*) within households (*h*) within counties (*c*) (Raudenbush & Bryk, 2002). At the first level, VKT is a function of vehicle-level independent variables plus a vehicle-level error term:

$$Y_{vhc} = \beta_{0hc} + \beta_{1hc} W_{1vhc} + \cdots + \beta_{Dhc} W_{Dvhc} + r_{vhc},$$

[4] Statewide estimates from McMullen et al. (2016b) show that a 1.5-cent-per-mile fee is not revenue neutral to a 30-cent-per-gallon tax if the average fuel economy of the vehicle fleet is greater than 20 miles per gallon.

where

> Y_{vhc} is the VKT for vehicle *v* in household *h* in county *c*;
>
> β_{0hc} is the y-intercept term for household *h* in county *c*;
>
> β_{Dhc} are $d = 1, \ldots, D$ vehicle-level coefficients;
>
> W_{Dvhc} is the independent variable *d* for vehicle *v* in household *h* and in county *c*; and
>
> r_{vhc} is the vehicle-level random-effect term.

At the second level, variation between households is a function of household-level independent variables plus a household-level error term:

$$\beta_{0hc} = \pi_{00c} + \pi_{01c}X_{1hc} + \cdots + \pi_{0Ec}X_{Ehc} + e_{0hc},$$

where

> π_{00c} is the y-intercept term for county *c*;
>
> π_{0Ec} are $e = 1, \ldots, E$ household-level coefficients;
>
> X_{Ehc} is the independent variable *e* for household *h* in county *c*; and
>
> e_{0hc} is the household-level random-effect term.

At the third level, variation between counties is a function of county-level independent variables plus a county-level error term:

$$\pi_{00c} = \gamma_{000} + \gamma_{001}Z_{1c} + \cdots + \gamma_{00F}Z_{Fc} + u_{00c},$$

where

> γ_{000} is the y-intercept term;
>
> γ_{00F} are $f = 1, \ldots, F$ county-level coefficients;
>
> Z_{Fc} is the independent variable *f* in county *c*; and
>
> u_{00c} is the county-level random-effect term.

The first series of models are known as random-intercept models because the coefficients at the vehicle level and the household level are fixed. The second series of models are known as random-coefficient models because the coefficients at the vehicle level are fixed but the coefficient for fuel economy at the vehicle level is random. On the one hand, the random-intercept models estimate how household characteristics and county characteristics affect VKT. On the other hand, the random-coefficient models estimate how a household characteristic——radial distance to a population of 2,500—affects variation in the effect of fuel economy on VKT.

The following subsection describes the data from the 2009–2011 Oregon Travel Activity Survey (OTAS).

3.3 Data

Data are from a cross-sectional survey of travel behavior in the State of Oregon known as the 2009–2011 OTAS. The survey uses standard travel survey methods such as a random sample drawn from a sampling frame of residential addresses, a supplemental geographic sample, a supplemental choice sample, and a cellular telephone sample. In order to collect sufficient data to model travel behavior the 2009–2011 OTAS divides the State of Oregon into ten survey regions whose boundary is a metropolitan planning organization (MPO) or an ODOT planning region. In order to document travel on a typical weekday when school is in session the 2009–2011 OTAS survey periods in the ten survey regions are in a spring season (ODOT Region 3, ODOT Region 4, ODOT Region 5, Salem/Keizer MPO, and Bend MPO), a fall season (Central Lane MPO, Rogue Valley MPO, and Clark County, Washington), or a fall and a spring season (ODOT Region 2 and Metro) from March of 2009 to December of 2011. The sample sizes of the vehicle file and the household file in the 2009–2011 OTAS are 41,094 and 19,932, respectively.

Data at the vehicle level include information on the vehicles[5] in each household. VKT is the total kilometers each vehicle is driven for all trips on the travel day. Age is vehicle age in years. Gasoline price is the nominal gasoline price on the travel day in dollars per liter. Fuel economy is in kilometers per liter. Trips is the number of trips each vehicle made on the travel day. Type is vehicle type: automobile (automobile, car, or station wagon); van (cargo, mini, or passenger); SUV; or pickup truck.

Data at the household level include information on the economic characteristics and the locational characteristics of each household. Income is the total household income. Location is zero if the household is in an urban location, one otherwise.[6] Radial distance from a household to accumulate a population of 2,500 is in kilometers.

Data at the county level include information on the locational characteristics and the infrastructure characteristics of each county. Population density is the population per square kilometer (United States Bureau of the Census, 2012). Region is the ODOT region (Portland Metro, Willamette Valley and North Coast, Southwestern Oregon, Central Oregon, or Eastern Oregon) for each household address. Road density is the kilometers of city roads, county roads (county rural roads, county roads inside cities, and local access roads), and state roads (state highway roads) per square kilometer of land area.[7]

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[5] Vehicles use gasoline for fuel.

[6] The variable LOCTYPE in the household file of the 2009–2011 OTAS categorizes locations across the State of Oregon by five density types (Oregon Department of Transportation, 2013). Rural locations in the study are density type 1 (rural) locations plus density type 3 (rural near major center) locations. The rural density-type category includes locations where more than two miles is necessary to accumulate a population of 2,500 and more than fifteen miles is necessary to accumulate a population of 50,000. The rural near major center density-type category includes locations where more than one mile is necessary to accumulate a population of 2,500 but less than 15 miles is necessary to accumulate a population of 50,000.

[7] Road density excludes the kilometers of other state roads (campus roads, state fish and wildlife roads, state institution roads, state forest roads, state park roads, and roads other local agency roads) and miscellaneous agency roads (Army Corps of Engineers roads, Bureau of Indian Affairs and Indian Nation roads, Bureau of Land Management roads, military roads, national park roads, other federal agency roads, and United States National Forest) per square kilometer of land area (Oregon Department of Transportation, 2011).

The following subsection hypothesizes on the effects of the vehicle-level independent variables, the household-level independent variables, and the county-level independent variables on VKT.

3.4 Effect Hypotheses

At the vehicle level, VKT should decrease with age because fuel economy is lower for older vehicles. Price sensitivity (Litman, 2013) suggests VKT should decrease with gasoline price. VKT should increase with fuel economy because the marginal costs of travel decrease (Blair et al., 1984; Crandall, 1992). VKT should be higher for automobiles than vans, SUVs, or pickup trucks.

At the household level, income tends to increase VKT (Liddle, 2009). Meanwhile, VKT increases in less-populous locations (Ke & McMullen, 2017; McMullen et al., 2016a).

At the county level, population density and region control for differences in demand. Road density controls for differences in infrastructure across the State of Oregon.

The following section presents the results from the models for VKT from the 2009–2011 OTAS.

4.0 Results

4.1 Models

The random-intercept model helps to understand how household-level independent variables and county-level independent variables affect VKT. Descriptive statistics for vehicle-level data, household-level data, and county-level data from the 2009–2011 OTAS are in Table 1. Coefficient estimates for the linear (VKT) dependent variable and the natural log (lnVKT) dependent variable are in Table 2. The intraclass correlation (ICC)—an estimate of the VKT correlation between two randomly-selected vehicles from the same household from the random-intercept model—is 16.37% (Hox, 2002; Raudenbush & Bryk, 2002). The explained proportion of variance for random-effects models is an analog to the coefficient of determination for fixed-effects models (Snijders & Bosker, 1999). The explained proportion of variance between the full model and the null model is 12.54%. That is, all of the vehicle-level independent variables, all of the household-level independent variables, and all of the county-level independent variables explain 12.54% of the variation in the vehicle-level dependent variable (VKT). The latter is low in comparison to coefficient-of-determination results from fixed-effects models of household VKT of about 25% from Ke and McMullen (2017).

The results at the vehicle level are consistent with the effect hypotheses. VKT is lower for older vehicles. A one standard deviation increase in age (6.54 years) decreases VKT by −3.99 kilometers. VKT decreases as gasoline price increases. A one standard deviation increase in gasoline price (0.15 dollars per liter) decreases VKT by −5.35 kilometers. Consistent with the effect hypothesis, the effect of fuel economy on VKT is positive. A one standard deviation increase in fuel economy (2.62 kilometers per liter) increases VKT by +1.31 kilometers.

Table 1: *Descriptive Statistics*

Level (n) **Variable**	**Category**	**Mean**	**SD**
Vehicle (18,514)			
VKT		45.94	41.45
lnVKT		3.44	0.91
Age (Years)		11.64	6.54
Gasoline Price (Dollars per Liter)		0.81	0.15
Fuel Economy (Kilometers per Liter)		9.69	2.62
Trips		11.17	7.71
Type			
	Car	54.02%	
	Van	9.54%	
	SUV	20.10%	
	Pickup Truck	16.34%	
Household (13,113)			
Income			
	Less than $25,000	10.52%	
	$25,000 to $49,999	21.58%	
	$50,000 to $74,999	24.26%	
	$75,000 to $99,999	20.50%	
	Greater than or equal to $100,000	23.14%	
Location			
	Rural	25.10%	
	Urban	74.90%	

Table 1 continued

Radial Distance to a Population of 2,500 (Kilometers)		2.28	4.24
County (35)			
Population Density (Population per Square Kilometer)		43.47	118.23
Region			
	Portland Metro	25.50%	
	Willamette Valley and North Coast	39.69%	
	Southwestern Oregon	16.36%	
	Central Oregon	11.72%	
	Eastern Oregon	6.74%	
Road Density (Kilometers per Square Kilometer)		0.58	0.76

Note: SD = Standard Deviation.

The results at the household level are somewhat consistent with the effect hypotheses. VKT is −2.02 kilometers lower, not higher, in the highest-income category (greater than or equal to $100,000) than the referent-income category ($50,000 to $74,999). Consistent with the effect hypothesis, the effect of location is positive. VKT is +14.44 higher in rural locations than urban locations and a one standard deviation increase in radial distance to a population of 2,500 (4.24 kilometers) increases VKT by +6.57 kilometers.

The results at the county level are consistent with the effect hypotheses. The effect of population density on VKT is negative. A one standard deviation increase in population density (118.23 per square kilometer) decreases VKT by −31.92 kilometers. VKT is +14.61 kilometers higher in the Portland Metro region than the referent region (Willamette Valley and North Coast), while VKT is −9.42 kilometers lower in the Eastern Oregon region than the referent region (Willamette Valley and North Coast). The effect of road density on VKT is positive. A one standard deviation increase in road density (0.76 kilometers per square kilometer) increases VKT by +33.49 kilometers.

Table 2: *Random-Intercept Model Results*

Level **Variable**	**Category**	**VKT**	**lnVKT**
Vehicle			
Age (Years)		−0.61 (0.06)***	−0.01 (0.001)***
Gasoline Price (Dollars per Liter)		−35.65 (5.76)***	−0.54 (0.10)***
Fuel Economy (Kilometers per Liter)		+0.50 (0.23)**	+0.01 (0.004)**
Trips		+1.35 (0.06)***	+0.03 (0.002)***
Type			
	Car	Referent	Referent
	Van	+1.09 (1.03)	+0.03 (0.02)
	SUV	+0.27 (0.85)	+0.01 (0.02)
	Pickup Truck	−0.20 (0.79)	−0.01 (0.02)
Household			
Income			
	Less than $25,000	+0.24 (1.12)	−0.06 (0.03)
	$25,000 to $49,999	+0.65 (1.02)	−0.004 (0.02)
	$50,000 to $74,999	Referent	Referent
	$75,000 to $99,999	−1.90 (1.03)*	−0.05 (0.02)**
	Greater than or equal to $100,000	−2.02 (1.04)*	−0.05 (0.02)**
Location			
	Rural	+14.44 (1.37)***	+0.45 (0.03)***
	Urban	Referent	Referent

Table 2 continued

Radial Distance to a Population of 2,500 (Kilometers)		+1.55 (0.19)***	+0.03 (0.004)***
<u>County</u>			
Intercept		+36.56 (2.10)***	+3.17 (0.07)***
Population Density (Population per Square Kilometer)		−0.27 (0.07)***	−0.01 (0.002)***
Region			
	Portland Metro	+14.61 (5.57)**	+0.34 (0.13)**
	Willamette Valley and North Coast	Referent	Referent
	Southwestern Oregon	+2.42 (3.62)	+0.09 (0.10)
	Central Oregon	−1.57 (4.15)	−0.03 (0.11)
	Eastern Oregon	−9.42 (3.98)**	−0.27 (0.11)**
Road Density (Kilometers per Square Kilometer)		+44.07 (12.06)***	+1.12 (0.33)***

Notes: Standard Errors (SE) appear in parentheses. *, **, and *** indicate significance at 90%, 95%, and 99% confidence levels, respectively. Referent category represents the highest-frequency category.

The random-coefficient model helps to understand how a household characteristic (radial distance to a population of 2,500) affects variation in the effect of fuel economy on VKT (see Table 3).

Table 3: *Random-Coefficient Model Results*

Variable	**Category**	**VKT**	**lnVKT**
Fuel Economy (Kilometers per Liter)			
Intercept		+0.84 (0.27)***	+0.02 (0.01)***
Income			
	Less than $25,000	−0.79 (0.41)*	−0.01 (0.01)
	$25,000 to $49,999	−0.70 (0.46)	−0.01 (0.01)
	$50,000 to $74,999	Referent	Referent
	$75,000 to $99,999	+0.04 (0.37)	−0.004 (0.01)
	Greater than or equal to $100,000	−0.46 (0.39)	−0.01 (0.01)
Location			
	Rural	−0.01 (0.40)	+0.001 (0.01)
	Urban	Referent	Referent
Radial Distance to a Population of 2,500 (Kilometers)		+0.10 (0.05)**	+0.002 (0.001)*

Notes: Standard Errors (SE) appear in parentheses. *, **, and *** indicate significance at 90%, 95%, and 99% confidence levels, respectively. Referent category represents the highest-frequency category.

The results at the household level are consistent with the effect hypotheses. VKT is −0.79 kilometers lower in the lowest-income category (less than $25,000) than the referent-income category ($50,000 to $74,999). Consistent with the effect hypothesis, the effect of location is positive. A one standard deviation increase in radial distance to a population of 2,500 (4.24 kilometers) slightly increases VKT by +0.42 kilometers.

Figure 1 is a graphic from the random-intercept model results to help visualize variation in the effect of fuel economy on travel demand (VKT) by location (radial distance to a population of 2,500). The y-intercepts for the 25th percentile and the 50th percentile of the radial-distance-to-a-population-of-2,500 distribution are about +34.34 kilometers and the y-intercept for the 75th percentile of the radial-distance-to-a-population-of-2,500 distribution is about +36.02 kilometers. In order to conservatively estimate variation in the effect of fuel economy on travel demand (VKT) by location, the center of the fuel economy distribution (+11.35 kilometers per liter) is a suitable point of reference. VKT at the 25th percentile is about +39.39 kilometers at the center of the fuel economy distribution, VKT at the 50th percentile is about +40.24 kilometers at the center of the fuel economy distribution, and VKT at the 75th percentile is about +43.61 kilometers at the center of the fuel economy distribution. Therefore, the VKT difference of +4.22 kilometers is the point estimate of the VKT difference for a given fuel economy in less-populous locations (75th percentile of the radial-distance-to-a- population-of-2,500 distribution) versus more-populous locations (25th percentile of the radial-distance-to-a-population-of-2,500 distribution). The slopes for the 25th percentile, the 50th percentile, and the 75th percentile of the radial-distance-to-a-population-of-2,500 distribution are +0.30, +0.35, and +0.56, respectively. Literal interpretation of the graphic is as follows. First, the positive slopes are graphic evidence that travel demand (VKT) increases with fuel economy regardless of geographic location. Second, the higher, positive slope for the 75th percentile of the radial-distance-to-a-population-of-2,500 distribution is graphic evidence that the increase in travel demand (VKT) with fuel economy is greater in less-populous locations.

4.2 Scenarios

The first price scenario is the fuel-tax scenario where drivers pay a 7.93-cent-per-liter (30-cent-per-gallon) fuel tax. The household mean in the fuel-tax scenario (n = 13,113) is 0.56 dollars with a range of 4.82 dollars from a minimum of 0.01 dollars to a maximum of 4.83 dollars. A parametric test—independent group *t*-test—shows that the difference between the mean fuel tax in dollars for rural households (n_R = 3,218, μ_R = 0.78, σ_R = 0.61) and the mean fuel tax in dollars for urban households (n_U = 9,895, μ_U = 0.49, σ_U = 0.48) is statistically different from zero (t (df = 4,543) = −24.44, p < 0.0001). The second scenario is the user-fee scenario where drivers pay a 0.93-cent-per-kilometer (1.5-cent-per-mile) user fee. The household mean in the user-fee scenario (n = 13,113) is 0.60 dollars with a range of 4.39 dollars from a minimum of 0.04 dollars to a maximum of 4.43 dollars. A parametric test—independent group *t*-test—shows that the difference between the mean user fee in dollars for rural households (n_R = 3,218, μ_R = 0.82, σ_R = 0.62) and the mean user fee in dollars for urban households (n_U = 9,895, μ_U = 0.54, σ_U = 0.50) is statistically different from zero (t (df = 4,645.6) = −23.70, p < 0.0001). Consistent with the empirical evidence from the 2009–2011 OTAS (McMullen et al., 2016a), total revenue from the user-fee scenario is greater than total revenue from the fuel-tax scenario ($7,926.52 versus $7,364.60). The third price scenario adjusts the user fee drivers pay so revenue per vehicle is neutral to the first price scenario where drivers pay a 7.93-cent-per-liter (30-cent-per-gallon) fuel tax. The mean user fee in the third price scenario is 0.87 cents per kilometer with a range of 1.66 cents per kilometer from a minimum of 0.21 cents per kilometer to a maximum of 1.86 cents per kilometer.

Figure 1. Variation in the effect of fuel economy on travel demand (VKT) by location (radial distance to a population of 2,500).

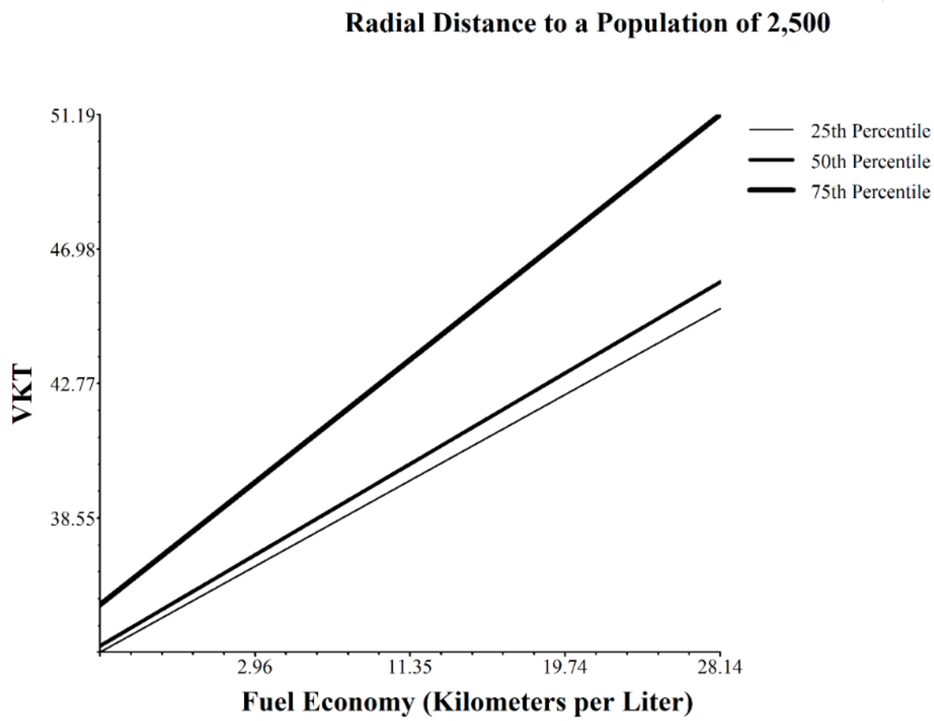


Figure 2 and Figure 3 are thematic maps known as isarithmic maps (Slocum et al., 2005) to help visualize the pattern of households from the OTAS subsample with a low probability (0% to 25%) versus a high probability (75% to 100%) of exceeding the mean fuel tax (0.56 dollars) in the first price scenario and the mean user fee (0.60 dollars) in the second price scenario, respectively. Figure 4 is an isarithmic map to help visualize the pattern of vehicles from the OTAS subsample with a low probability (0% to 25%) versus a high probability (75% to 100%) of exceeding the 0.93-cent-per-kilometer (1.5-cent-per-mile) user fee in the third price scenario. The labels for the ODOT regions in the respective isarithmic maps help discriminate low-probability fills from high-probability fills within the ODOT regions across the State of Oregon and between the ODOT regions across the State of Oregon.[8] The patterns of low-probability fills versus high-probability fills from the first price scenario (see Figure 2) and the second price scenario (see Figure 3) show great variation within each ODOT region. Put succinctly, the fills in each ODOT region range from the lowest-probability category to the highest-probability category. The within-ODOT-region variation supports the contention that the rural–urban divide is, at best, a crude discriminator of travel demand across the State of Oregon (Crandall & Weber, 2005; Ke & McMullen, 2017; McMullen et al., 2016a). Further, the highest-probability fill (75% to 100%) is only evident in Central Oregon and Eastern Oregon in the third price scenario (see Figure 4). The central orientation and the eastern orientation of the highest user fees in the

[8] Isarithmic maps represent the interpolation of unknown data values from known data values for the households in the OTAS subsample (see Figure 2 and Figure 3) and the vehicles in the OTAS subsample (see Figure 4).

third price scenario supports the contention that adjustments to user fees in order to account for the effect of fuel economy on travel demand (VKT) should help encourage usage of green vehicles (Larsen et al., 2012). To that end, the difference in user fees for the most frequent makes–models in OReGO in the third price scenario with divergent fuel economy are great. On the one hand, the user fee in the third price scenario for the 22.06-kilometer-per-liter (51.89-mile-per-gallon) Toyota Prius (n = 172) is 0.36 cents per kilometer (0.58 cents per mile). On the other hand, the user fee in the third price scenario for the 6.61-kilometer-per-liter (15.55-mile-per-gallon) Ford F-150 (n = 385) is 1.20 cents per kilometer (1.93 cents per mile).

Figure 2. Probability of higher-than-mean, household fuel tax (0.56 Dollars).

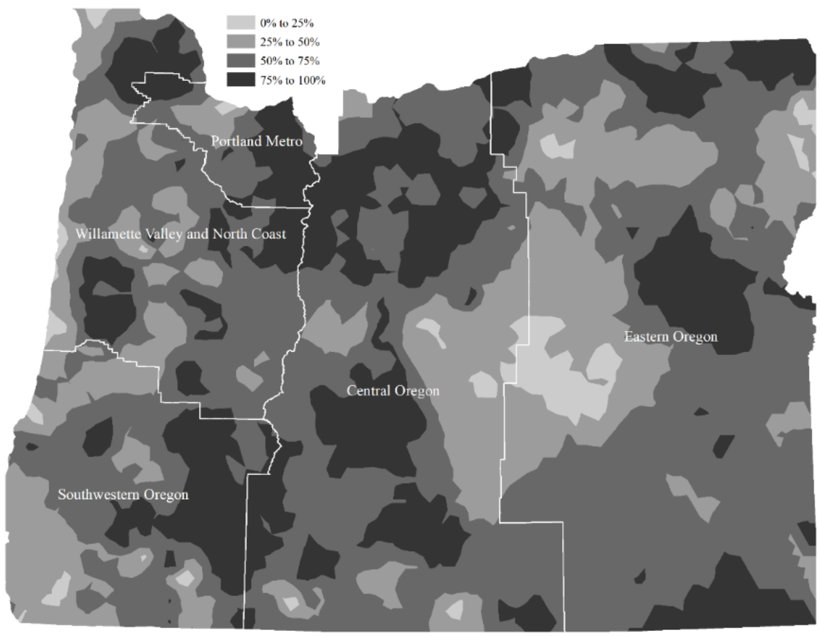


Figure 3. Probability of higher-than-mean, household user fee (0.60 Dollars).

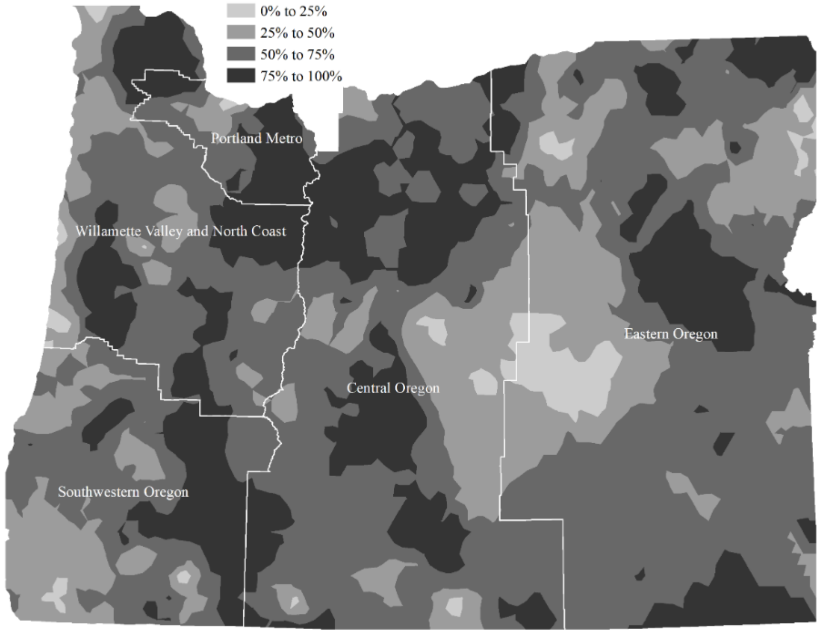
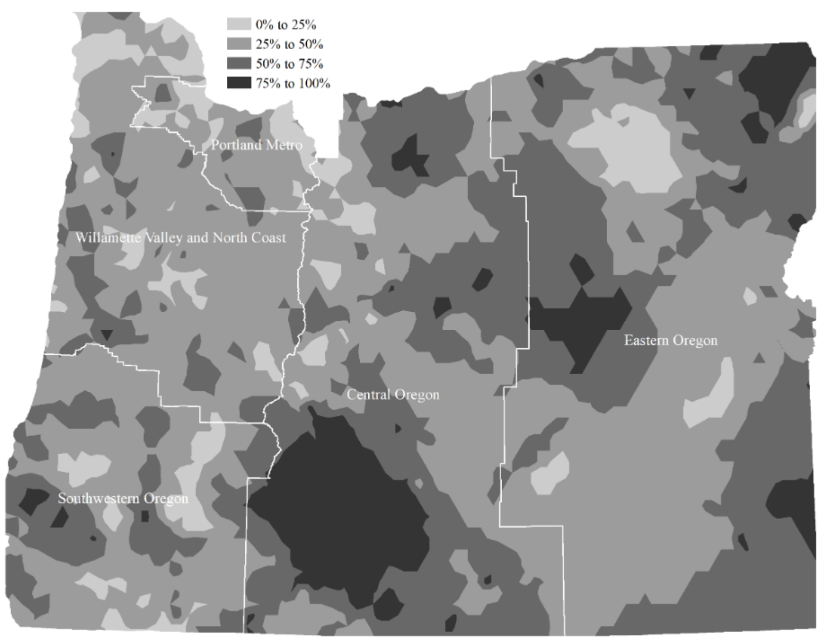


Figure 4. Probability of higher than 0.93-cent-per-kilometer (1.5-cent-per-mile) user fee per vehicle.



The following section highlights the implications of the results on the implementation of user-fee programs.

5.0 Discussion

The use of disaggregated data on household travel demand for an entire state unmasks an increase in demand with fuel economy more so in less-populous locations. A price scenario which is revenue neutral to the present 30-cent-per-gallon fuel tax adjusts for the magnitude of the effect of fuel economy on travel demand at the micro, or the vehicle, level. The adjusted price scenario therefore encourages green vehicle usage even if drivers in less-populous locations are still somewhat more likely to incur higher user fees. The latter result may not change public perception of an inequity in user-fee programs particularly for drivers of green vehicles, but such a result is perhaps not surprising from the perspective of the travel behavior literature. Indeed, the empirical evidence suggests that, in general, perceptions match reality with regard to travel distances (Canter & Tagg, 1975). However, distance bias is more frequent for unknown locations (Golledge & Zannaras, 1973) which could help explain why the public overestimates inequity with regard to distance.

6.0 Conclusions

The contributions of the results to the empirical literature on equity in user-fee programs are a function of the data and the design of the study. The use of disaggregated data on travel demand unmasks how households use vehicles, particularly green vehicles, slightly differently by geographic location. The decision to control for the effect of fuel economy on travel demand (Kastrouni et al., 2015) highlights slight differences by geographic location. To that end, the most important contribution of the study to the equity literature on user-fee programs is that VKT for households in less-populous locations is slightly greater than for households in more-populous locations especially as fuel economy increases. Nonetheless, the public seems to overestimate the magnitude of the inequity probably because such locations are less familiar.

Future research to replicate the results on greater demand by drivers of higher fuel economy vehicles in less-populous locations is necessary to ensure that such results are not a temporal artifact. Indeed, the disaggregated data in the study roughly coincides with a recession where macroeconomic contraction is likely to have adversely affected travel demand. To that end, one plausible explanation for the results is that drivers in less-populous locations adjust to economic downturns by using higher fuel-economy vehicles for more daily trips. New disaggregated data from nationwide sources and statewide sources could help test for temporal changes in vehicular travel demand before and after the Great Recession from December of 2007 to June of 2009. If the results of such research are consistent with the results from the present study, then more research on how to better adjust user-fee systems is necessary to ensure equity after program implementation.

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