Research Article

Data-Driven Analysis of Rural Equity and Cost Concerns for Mileage-Based User Fees in Vermont

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Abstract

Examining substitutes to the current state and federal gasoline and diesel fuel excise taxes has become a pressing issue, exacerbated by the rise of high-efficiency and alternative-fuel vehicles threatening the revenue-generating capacity of these taxes. A mileage-based user fee has been frequently proposed in the literature as an alternative that would offer greater benefits to rural and low-income populations than to urban and higher-income populations. However, most prior analyses relied on small data sets and aggregated data. This study examined the impact of replacing the Vermont state fuels tax with a revenue-neutral, mileage-based user fee using mileage and fuel economy data for over 300,000 registered passenger vehicles. We found that, on average, Vermont households would pay an additional $23 per year, with rural households and low-income households facing smaller tax burdens than their urban and high-income counterparts. The impact of a $180 flat fee replacing the Vermont state motor fuels tax was also examined owing to state interest. Findings indicated that a flat fee would result in much larger price fluctuations, with most households paying an additional $47 per year. The disaggregated data approach presented here directly addresses public misconceptions of inequitable cost differences and provides context for public education campaigns to garner mileage-based user fee policy support. Based on our results, there is political ground for further research into the implementation of a mileage-based user fee, including the logistics of an administrative transition to mileage charging and the associated program implementation and technological costs.

There is consensus that the sustainability of transportation funding in the United States is at risk. Maintaining existing roadway networks is becoming a greater burden (*1–3*), and current revenue generation methods are failing to keep up. Currently, the motor fuels tax or "gas tax" represents the largest proportion of funding for roadway maintenance and construction. In almost all states and at the federal level, the gas tax is an excise tax implemented as a flat tax per unit of gasoline or diesel fuel sold. As a flat per gallon tax, the revenue collected though the gas tax is infrequently adjusted to inflation. Some states have recognized this limitation and have passed legislation to index the gas tax to inflation, but this is not common practice (*4–8*). Critics of the gas tax also note that the rising adoption of more fuel-efficient, hybrid, and electric vehicles has further eroded gas tax revenue (*6, 9–11*). With the current trajectory of rising inflation combined

with state and federal policies aimed at further increasing the fuel efficiency of the vehicle fleet and electric vehicle adoption, the United States can expect a significant gap in transportation funding in the coming decades.

In addition to declining revenue and purchasing power, the gas tax is frequently found to be regressive and inequitable, with low-income and rural households facing higher tax burdens owing in part to their propensity to own less fuel-efficient vehicles, and in some situations to drive more (*5, 12–15*). In response to concerns over the gas tax, a variety of funding alternatives have

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been examined, including congestion charging, tolling, and road-user fees (*4*, *16–19*). States have also explored supplementing transportation funding through increases in local option taxes such as income, property, and sales taxes, although there are concerns over the long-term financial viability of these options (*16*, *19*).

Road-user fees based on mileage, commonly referred to as a mileage-based user fee (MBUF), are actively being pursued by governing agencies as a more sustainable replacement for the gas tax. However, public concerns and misconceptions about MBUFs remain a significant implementation barrier (*4*, *20*). Based on prior surveys and focus-group efforts at local, state, and federal levels, public hesitancy mainly focuses on three main concepts: perceptions of the personal tax burden (as in believing an MBUF would be much more expensive than their current gas tax payments), perceptions of inequity (as in believing an MBUF would be largely unfair to rural and low-income communities), and privacy concerns (related to discomfort with any governing body or agency knowing or tracking their mileage). Studies estimating changes in tax burdens under MBUFs have found minimal differences in per-household and per-capita costs compared with the gas tax at both statewide and national scales (*21–29*). Several studies have also considered the impacts on households in different community types, finding that rural households would tend to benefit more from an MBUF than urban households would (*22–26*, *30*, *31*). Studies have also found that low-income households would have lower tax burdens than higher-income households (*23*, *27*, *32*).

Although these studies have begun to address public equity concerns revolving around MBUFs, there are potential pitfalls in their use of sparse and aggregate data to evaluate MBUF policies. In most cases, these studies used the National Household Travel Survey (NHTS) to examine tax burden. MBUF policy analyses based on NHTS data are limited by the survey's aggregation of respondent locations and the small sample sizes for small and medium-sized communities. The resulting analyses are, therefore, limited in their ability to discern the full range of cost variation across the diverse range of community types within states. Furthermore, the NHTS provides data from only one day of travel, so researchers must rely on extrapolation to assess monthly or annual household cost differences under an MBUF.

There are currently efforts to expand on prior MBUF equity research with larger vehicle data sets. For example, the Hawaii Road-User Charge (HiRUC) study used state vehicle registration records to estimate tax payments for each registered vehicle in Hawaii. The HiRUC study found that rural and low-income households would, on average, save money compared with their urban and higher-income counterparts (*33*). These findings illustrate the value of using disaggregated data to explore the full range of costs experienced by households on the rural to urban and high to low-income spectrums.

Vermont Context

The Vermont Agency of Transportation (VTrans) is evaluating options to increase state transportation revenue through taxes on electric and hybrid vehicles. A recent study from VTrans has confirmed that Vermont will experience significant funding deficits if the gas tax is not increased, supplemented, or replaced in the coming years. By assuming Vermont's socioeconomic and geographical landscape is comparable to states that have previously studied the financial and equity implications of replacing the gas tax with an MBUF, the VTrans study concludes that a revenue-neutral MBUF ranging from 1.3 to 1.5 cents per mile would be a reasonable replacement for the state gas tax and has the potential to bridge impending funding gaps (*34*).

Our study expands on this state interest to perform a robust analysis of disaggregated vehicle data available from the Vermont Department of Motor Vehicles. We overcame the prior limitations of research relying on small data sets and aggregated location information to provide novel insights into the true costs of replacing the gas tax with either an MBUF or a flat vehicle fee at the per-vehicle, per-household, and per-capita level. Our focus on Vermont, a primarily rural state, directly addresses public concerns about the equity of an MBUF for populations residing in a wide range of communities with various levels of income from diverse racial and ethnic groups.

Methods

The vehicle data we used in this study were originally collected by the University of Vermont Transportation Research Center for the 2021 Vermont Transportation Energy Profile (*35*). These data were further cleaned and analyzed for this report.

Data Source

Since 2016, Vermont has required all registered vehicles to be inspected every 365 days using a new electronic inspection reporting system. During each inspection, vehicle identification numbers (VINs) and odometer readings are recorded. Registration records are also available for each VIN, containing information about vehicle attributes and the registered vehicle address. We obtained additional details about each vehicle by querying an NHTSA database that decodes information

contained within each VIN using an API developed for R (*36*).

Data Cleaning

We calculated annual vehicle miles traveled (VMT) for each vehicle using odometer readings from subsequent years and normalizing by the number of days between inspections. The inspection data were then merged with vehicle registration records using VINs, which linked VMT data to home addresses. Detailed information about each vehicle obtained by decoding the VINs was then used to pair vehicles with fuel economy ratings available from the U.S. Environmental Protection Agency's fuel economy database (*37*).

Publicly available Enhanced 911 (E911) data for Vermont contains additional information on each address in Vermont, including a commercial–residential address indicator. We identified and removed all vehicles registered at nonresidential addresses from our data. We also removed vehicles with a gross vehicle weight greater than 14,000 lb (Class 3 and above), leaving us with a data set containing mostly light-duty personal vehicles. This allowed us to evaluate the impact of gas tax alternatives on individuals and households. We then filtered the data to exclude any vehicles that could not be matched with a fuel economy estimate. The final data set contained 310,661 vehicles across 189,251 households.

Each vehicle was geocoded to its registered home street address using ArcGIS. The geocoded vehicle point locations were then spatially intersected with race and income data from the 2019 American Community Survey as well as community-type indicators from the 2010 U.S. Department of Agriculture rural–urban commuter area codes (RUCA codes).

Revenue-Neutral Fee Calculation

The final data were analyzed to identify financial inequities across Vermont populations if the Vermont state gas tax was replaced by either an MBUF or a flat fee.

The MBUF and flat fee were calculated as revenue-neutral fees to discern the baseline impacts of a change in transportation revenue collection. From the latest Federal Highway Administration highway statistics report (*38–41*), 289.164 million gallons of gasoline and 72.796 million gallons of diesel were purchased in Vermont in 2018. The annual Vermont gas tax revenue was calculated by multiplying each quantity of purchased fuel by their respective state taxes ($ 0.307 per gallon of gasoline purchased and $ 0.31 per gallon of diesel purchased). This annual revenue was then divided by the estimated total annual Vermont VMT (7.346 billion miles) to calculate the MBUF and divided by the total number of registered vehicles in Vermont to calculate the flat fee. The resulting revenue-neutral taxes were determined to be $ 0.015 per mile or $180 per vehicle per year. The calculation for the revenue-neutral MBUF is shown in Equation 1.

$$MBUF = \frac{T_{gas}Q_{gas} + T_{diesel}Q_{diesel}}{VMT_{total}} \qquad (1)$$

where

$MBUF$ = revenue-neutral MBUF,
T_{gas} = Vermont state gas tax,
Q_{gas} = total gallons of gasoline fuel purchased in Vermont,
T_{diesel} = Vermont state diesel tax,
Q_{diesel} = total gallons of diesel fuel purchased in Vermont, and
VMT_{total} = total annual Vermont VMT estimate.

Note that the revenue-neutral mileage fee was calculated using total mileage and vehicle count estimates from Vermont, which included heavy-duty and commercial vehicles. Since our data were filtered to only include light-duty personal vehicles, the revenue-neutral mileage fee calculated in Equation 1 would not necessarily result in a revenue-neutral change in costs for the subset of vehicles in our data.

Financial Impact

The tax burden of switching to either an MBUF or a flat fee were calculated as dollar and percent differences relative to current gas tax spending. Negative tax burdens translate to lower annual costs (saving money), whereas positive tax burdens translate to higher annual costs (spending more money).

This analysis was performed on a per-vehicle, per-household, and per-capita level. Calculations for per-vehicle, per-household, and per-capita costs are shown in Equations 2, 3, and 4 respectively. Household gas tax, flat fee, and MBUF costs were calculated by summing the per-vehicle tax burden at each address. Household costs were then normalized by the average household size in their census block to generate per-capita gas tax, flat fee, and MBUF cost estimates.

$$TB_{veh} = C_{gas} - C_{MBUF} \qquad (2)$$

$$TB_{hh} = \sum_{i} (TB_{veh})_i \qquad (3)$$

$$TB_{cap} = \frac{\sum_{i} (TB_{veh})_i}{HHS_j} \qquad (4)$$

where

TB_{veh} = tax burden for a vehicle,
TB_{hh} = tax burden for a household,
TB_{cap} = tax burden per-capita,

Table 1. RUCA Code Descriptions

RUCA code	Description	Aggregated RUCA codes
1	Metropolitan area core: primary flow within urbanized area	Area core
2	Metropolitan area high commuting: primary flow 30% or more to a UA	High commuting
3	Metropolitan area low commuting: primary flow 10% to 30% to a UA	Low commuting
4	Micropolitan area core: primary flow within an urban cluster of 10,000 to 49,999 (large UC)	Area core
5	Micropolitan area high commuting: primary flow 30% or more to a large UC	High commuting
6	Micropolitan area low commuting: primary flow 10% to 30% to a large UC	Low commuting
7	Small town core: primary flow within an urban cluster of 2,500 to 9,999 (UC)	Area core
8	Small town high commuting: primary flow 30% or more to a UC	High commuting
9	Small town low commuting: primary flow 10% to 30% to a UC	Low commuting
10	Rural areas: primary flow to a tract outside a UA or UC	Rural

Note: RUCA = rural–urban commuter area; UA = urbanized area; UC = urban cluster.

C_{gas} = annual gas tax costs for a vehicle,
C_{MBUF} = annual MBUF costs for a vehicle,
i = household (i.e., residential address),
j = census block group, and
HHS = average household size in a census block.

Spatial Analysis

The large number of vehicles and households used in the analysis were difficult to visualize on a statewide scale when using points. Spatial trends in tax burden were discerned by aggregating vehicle point data and, separately, aggregating household point data onto a statewide grid using a 2-km^2 cell size. The resulting 2,919 grid cells contained the mean gas tax, flat fee, and MBUF costs per vehicle, household, and capita within each cell. Of the 2,919 grid cells, 512 did not contain any vehicles. These "holes" on the map were mostly the result of the Green Mountains and other unpopulated natural areas, either privately owned or protected.

Equity Analysis

The tax incidence of an MBUF and a flat fee were examined across 10 income quantiles using the full, disaggregated data set (310,661 vehicles across 189,251 households). Tax burdens were assessed per vehicle, per household, and per capita. Incomes were obtained from median household income data available at the census block group level.

Race and ethnicity data were obtained at the census block level. Population-weighted household costs were calculated for each racial and ethnic group, as shown in Equation 5.
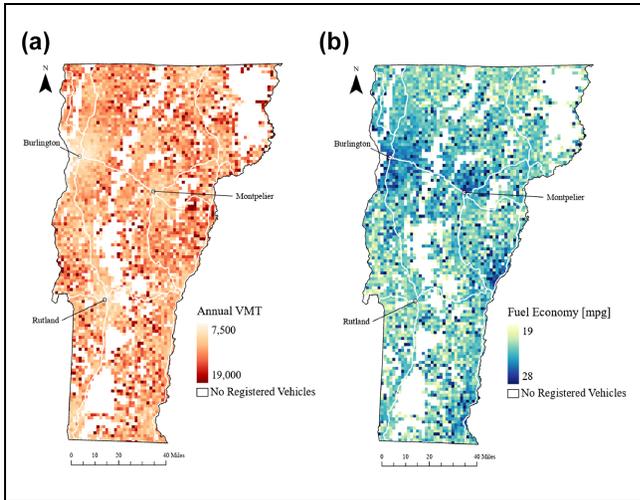
$$C_{rg} = \frac{\sum_j C_j P_j}{\sum_j P_j} \quad (5)$$

where
C_{rg} = population-weighted household cost for a racial and ethnic group,
C = mean annual household cost in a census block (either gas tax, flat fee, or MBUF), and
P = population of a racial and ethnic group in a census block.

Tax incidence was also evaluated across 10 distinct RUCA codes, which describe the single largest commuting share in a census tract. To reduce the number of variables, these codes were aggregated into four categories: area core, high-commuting, low-commuting, and rural (Table 1). When a tract is defined as an area core, it means more than 30% of the tract population is in an urbanized area and the primary flow is within the tract. When a tract is defined as high-commuting, it means the primary flow (accounting for over 30% of the tract population) is to a tract defined as an area core. When a tract is defined as low-commuting, it means the primary flow (accounting for less than 30% of the tract population) is to a tract defined as an area core. When a tract is defined as rural, it means the primary flow is within the tract or to other rural tracts.

Figure 1 provides spatial context for current vehicle use and ownership in Vermont. Annual gas tax payments were calculated using VMT and fuel efficiency for the full, disaggregated data. For easier visualization, mean values of VMT and fuel efficiency were estimated for each 2-km^2 grid cell in Figure 1. All maps also note the locations of major highways and interstates running through Vermont as well as for three Vermont cities: Burlington, Montpelier (the state capital), and Rutland.

Figure 1. Vermont spatial trends using mean values per 2-km² grid cell: (*a*) annual vehicle miles traveled (VMT) per vehicle, and (*b*) fuel economy in miles per gallon (mpg). Interstates running through Vermont are shown as white lines.

Results

In Vermont, annual gas tax payments average $150 per vehicle, $250 per household, and $131 per capita. Household gas tax expenditure tends to increase with distance from city centers. As Figure 2 shows, households near denser areas such as Burlington, Montpelier, and Rutland pay less in gas taxes compared with rural households. Annual household gas tax payments show a slightly progressive trend at the lowest income brackets (less than $55,000 per year), but Vermont households making anywhere from $55,000 per year to millions per year see little to no difference in costs.

Two alternatives to this current taxing scheme were examined: an MBUF and a flat fee.

Alternative 1: A Revenue-Neutral Flat Fee of $180 per Vehicle Per Year Replaces the VT Gas Tax

Under a revenue-neutral flat fee alternative, every vehicle owner (residential and commercial) would pay $180 per vehicle per year in taxes. The following analysis only includes personal light-duty vehicles to understand the impact on Vermont households.

Compared with the gas tax, a flat fee of $180 per vehicle per year results in higher annual payments on average when examined at the per-vehicle, per-household, and per-capita level. On average, each household would see a $50 increase in annual payments. Only 30% of Vermont residential households would save money. Most households (75%) see changes in tax burdens ranging from saving
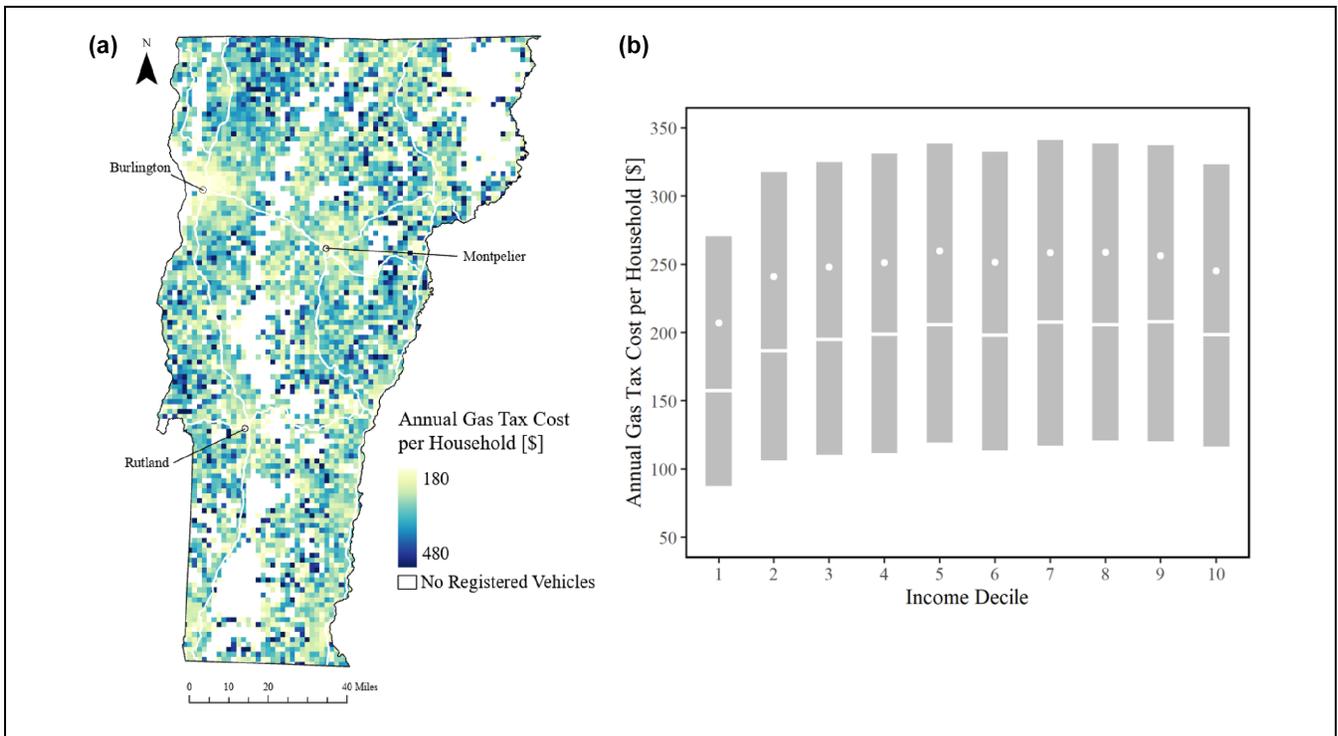

Figure 2. Annual gas tax burdens for Vermont households in 2019: (*a*) spatial distribution using mean values per 2-km² grid cell. Interstates running through Vermont are shown as white lines. (*b*) Income distribution using median census block group household incomes, with means for each income decile represented as a white dot.

Table 2. Summary Statistics for Annual Tax Burdens under the Gas Tax, an MBUF, or a Flat Fee

Variable		Min.	Q1	Median	Mean	Q3	Max.
Per vehicle							
Fuel economy, mpg		11	19	22.5	23.6	26.8	124.8
Annual VMT		0	6,162	9,949	11,003	14,418	99,905
Cost ($)	Gas tax	0	79.69	131.7	151.2	197.8	2,277
	MBUF	0	92.44	149.2	165.0	216.3	1,499
	Flat fee	180	180	180	180	180	180
Cost difference from gas tax ($)	MBUF	−915.0	−7.90	9.99	13.83	34.51	1,485.88
	Flat fee	−2,097	−17.78	48.26	28.79	100.3	180
Percent cost difference from gas tax (%)	MBUF	−46.25	−7.17	9.93	83.54	30.94	10,000
	Flat fee	−92.09	−8.99	36.64	309.8	125.9	3,389,811
Per household							
Cost ($)	Gas tax	0	111.2	195.7	247.6	326.6	6,771
	MBUF	0	130.7	219.6	270.3	353.9	5,338
	Flat fee	180	180	180	294.8	360	2,880
Cost difference from gas tax ($)	MBUF	−1,433	−5.61	16.71	22.65	47.13	1,474
	Flat fee	−4,251	−18.87	63.67	47.15	131.19	1,499
Percent cost difference from gas tax (%)	MBUF	−46.25	−2.98	10.56	51.03	28.59	10,000
	Flat fee	−91.86	−6.79	33.84	171.7	106.0	1,085,912
Per capita							
Cost ($)	Gas tax	0	53.14	95.33	131.3	164.9	8,942
	MBUF	0	62.18	107.4	143.0	179.43	8,350
	Flat fee	0.33	86.67	122.4	155.2	186.7	9,540
Cost difference from gas tax ($)	MBUF	−1,929	−2.68	8.07	11.72	23.41	2,078
	Flat fee	−3,665	−8.93	30.16	23.89	65.96	4,431
Percent cost difference from gas tax (%)	MBUF	−386.3	−1.43	5.1	43.74	14.28	10,000
	Flat fee	−487.8	−3.19	16.12	109.9	53.28	662,590

Note: MBUF = mileage-based user fee; VMT = vehicle miles traveled; Min. = minimum; Max. = maximum; Q1 = lower quartile; Q3 = upper quartile.

$19 per year to paying $131 more per year. This scenario creates extreme cost differences across Vermont, with 12% of households saving over $100 per year, but 36% of households spending an additional $100 per year or more. Full summary statistics for flat fee costs and tax burdens relative to annual gas tax costs are given in Table 2.

Where Vermonters live (their community type) and their income would significantly affect their annual tax burden if the gas tax is replaced with a flat fee. For example, high-income urban households typically pay $75 more than medium-income, low-commuting households (Table 3). On average, residents of urban areas would see cost increases double those of their rural counterparts. Middle-income households ($40,000 to $85,000) generally see the smallest price changes, and high-income earners (over $85,000) see the largest price increases. However, in high-commuting and urban areas, the lowest income earners would be responsible for the highest average costs per capita (Figure 3).

Alternative 2: A Revenue-Neutral Mileage-Based User Fee of $ 0.015 per Mile Replaces the VT Gas Tax

Under a revenue-neutral MBUF scenario, every vehicle would be charged a $ 0.015 per mile fee. The following analysis only includes light-duty vehicles registered at residential addresses to understand the impact on Vermont households.

Most Vermont households would pay between $130 and $350 in annual MBUF payments. This scenario would translate to most households paying somewhere between an additional $50 per year to $5 less. On average, this would be a $30 increase in annual tax burden and only 30% of Vermont residential households would save money. The cost differences at the high and low ends of the spectrum, however, are small compared with the cost differences associated with a flat fee, with only a few extreme cases of high savings (2%) and high losses (8%). Full summary statistics for MBUF costs and tax burdens compared with annual gas tax costs are given in Table 2. The variation in annual costs across income and community types would be minimal for MBUFs. For example, the largest annual cost difference would be between low-income, low-commuting households and low-income rural households, with the former paying $15 more on average (Table 3).

Keeping these small numbers in mind, residents of urban areas would pay up to 1.5 times the costs of their rural counterparts. Those living in commuting areas, also referred to as suburbs, would see similar or slightly larger

Table 3. Annual Change in Tax Burdens for Flat Fees and MBUFs Replacing the Gas Tax by Community Type and Income Level

Community type	Number households	Flat fee cost difference ($)			MBUF cost difference ($)		
		Per vehicle	Per household	Per capita	Per vehicle	Per household	Per capita
Low income							
Rural	2,707	19	30	19	10	17	10
Low commuting	64	27	41	23	21	32	21
High commuting	0	NA	NA	NA	NA	NA	NA
Urban	14,277	44	63	34	17	25	13
Medium income							
Rural	40,655	8	14	9	10	17	11
Low commuting	2,992	5	8	5	10	17	9
High commuting	37,243	15	26	14	11	20	10
Urban	53,722	49	75	37	16	25	13
High income							
Rural	3,716	27	46	28	17	28	16
Low commuting	0	NA	NA	NA	NA	NA	NA
High commuting	13,003	18	32	15	15	27	12
Urban	20,872	49	84	37	18	30	13

Note: MBUF = mileage-based user fee; low income = less than $40,000/year; medium income = $40,000 to $85,000/year; high income = more than $85,000/year. Cells with an NA indicate categories with no data, i.e., no households.
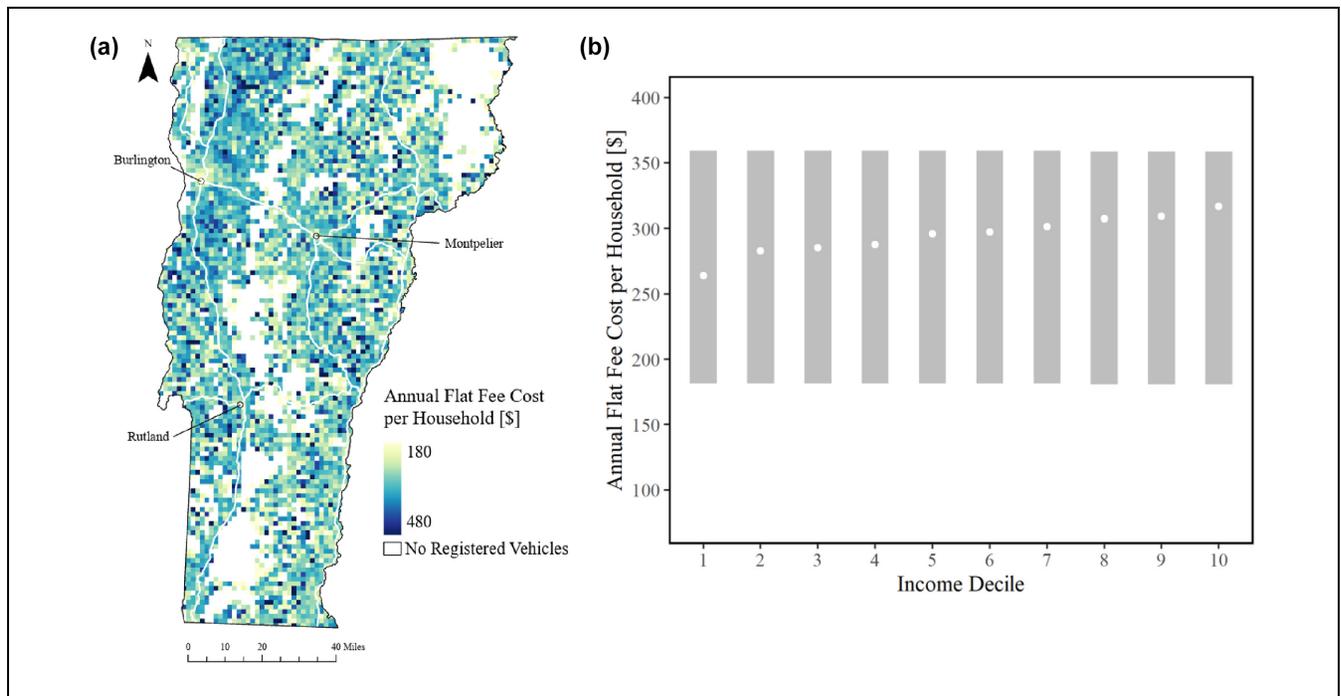

Figure 3. Annual flat fee tax burdens for Vermont households in 2019: (*a*) spatial distribution using mean values per 2 km^2 grid cell. Interstates running through Vermont are shown as white lines, and (*b*) Income distribution using median census block group household incomes, with means for each income decile represented as a white dot.

price increases compared with urban residents. Middle-income households ($40,000 to $85,000) experience the smallest price changes, whereas the highest income households (over $85,000) see the largest price increases (Figure 4).

Cost Variation Across Vermont Communities

When spatially examining policy alternatives to the gas tax across the state of Vermont, differences in costs between community types were evident (Figures 5 and 6). Areas farther from main city centers, generally
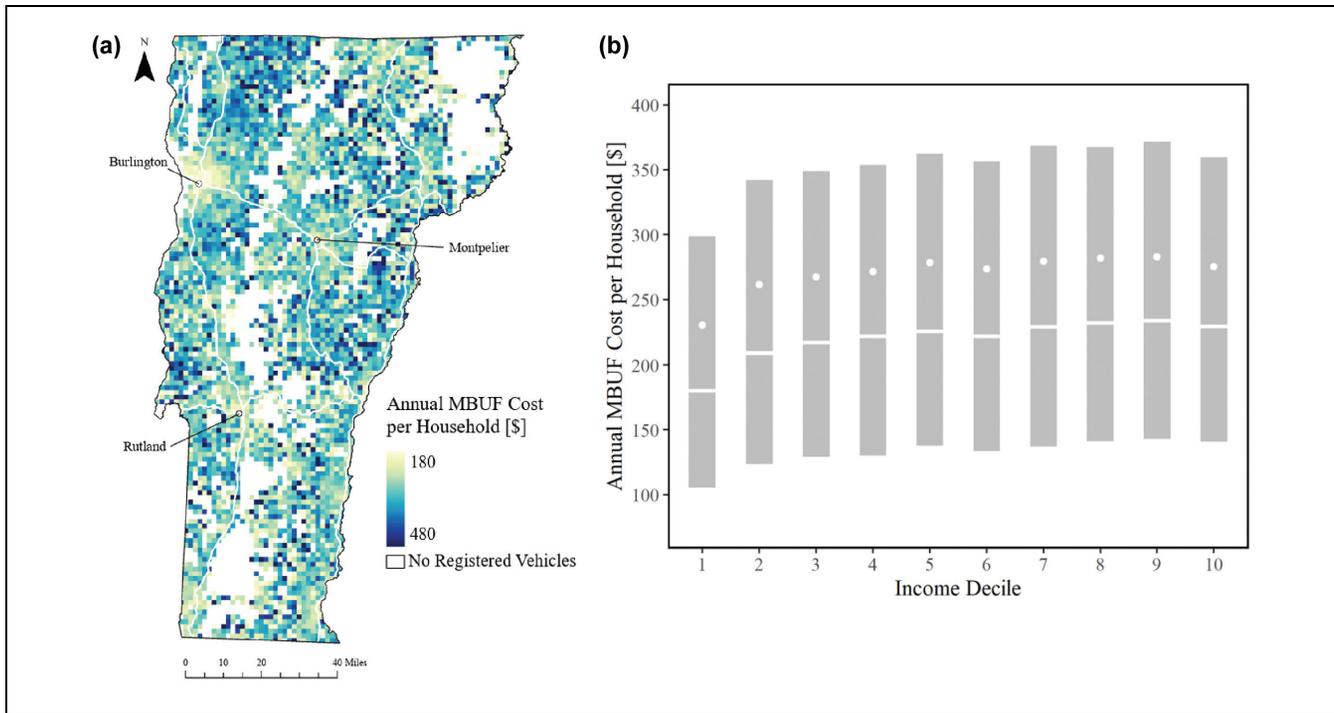
Figure 4. Annual mileage-based user fee (MBUF) tax burdens for Vermont households in 2019: (*a*) spatial distribution using mean values per 2-km² grid cell. Interstates running through Vermont are shown as white lines. (*b*) Income distribution using median census block group household incomes, with means for each income decile represented as a white dot.
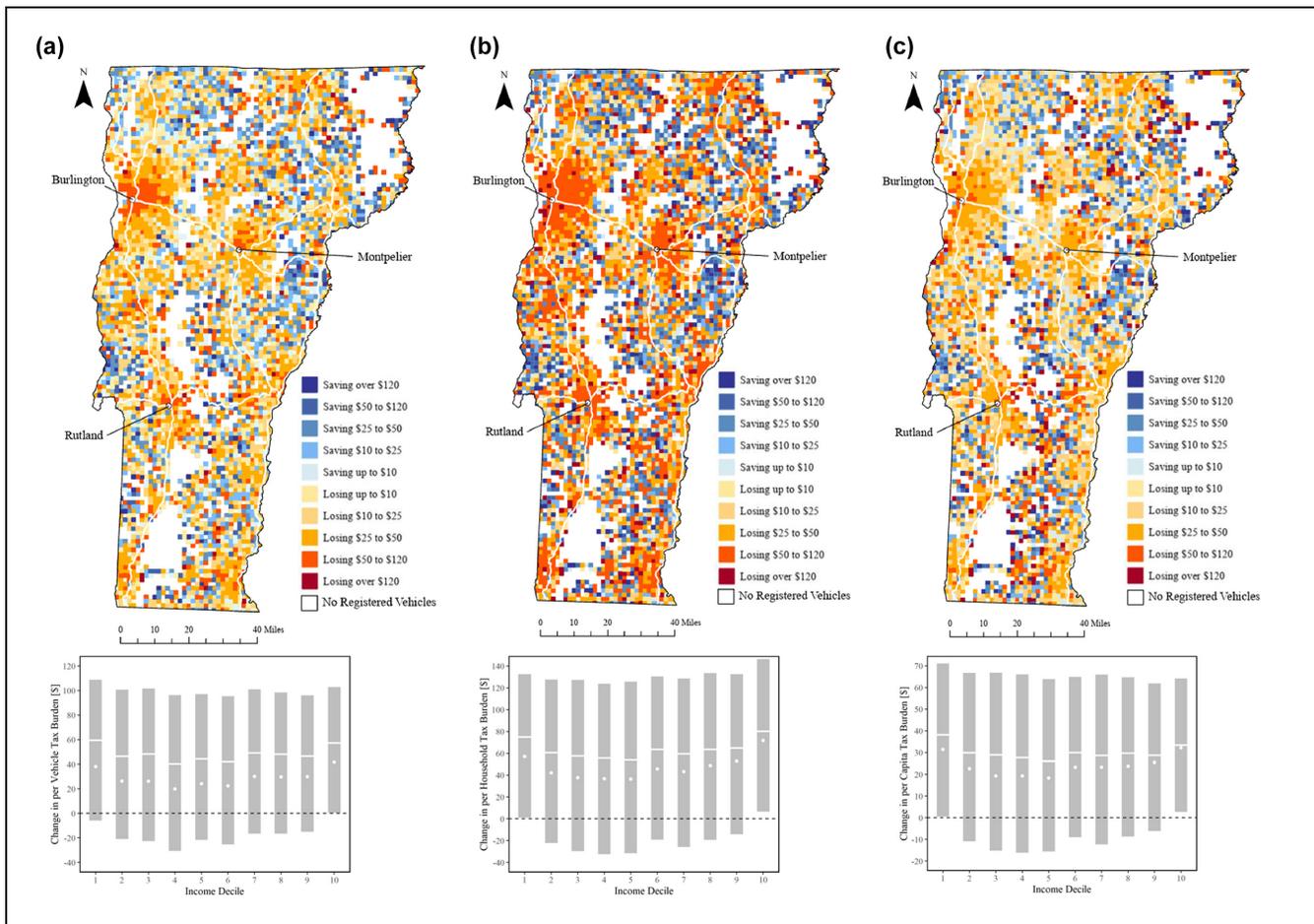

Figure 5. Annual change in tax burdens for flat fees replacing the gas tax: (*a*) per vehicle, (*b*) per household, and (*c*) per capita.
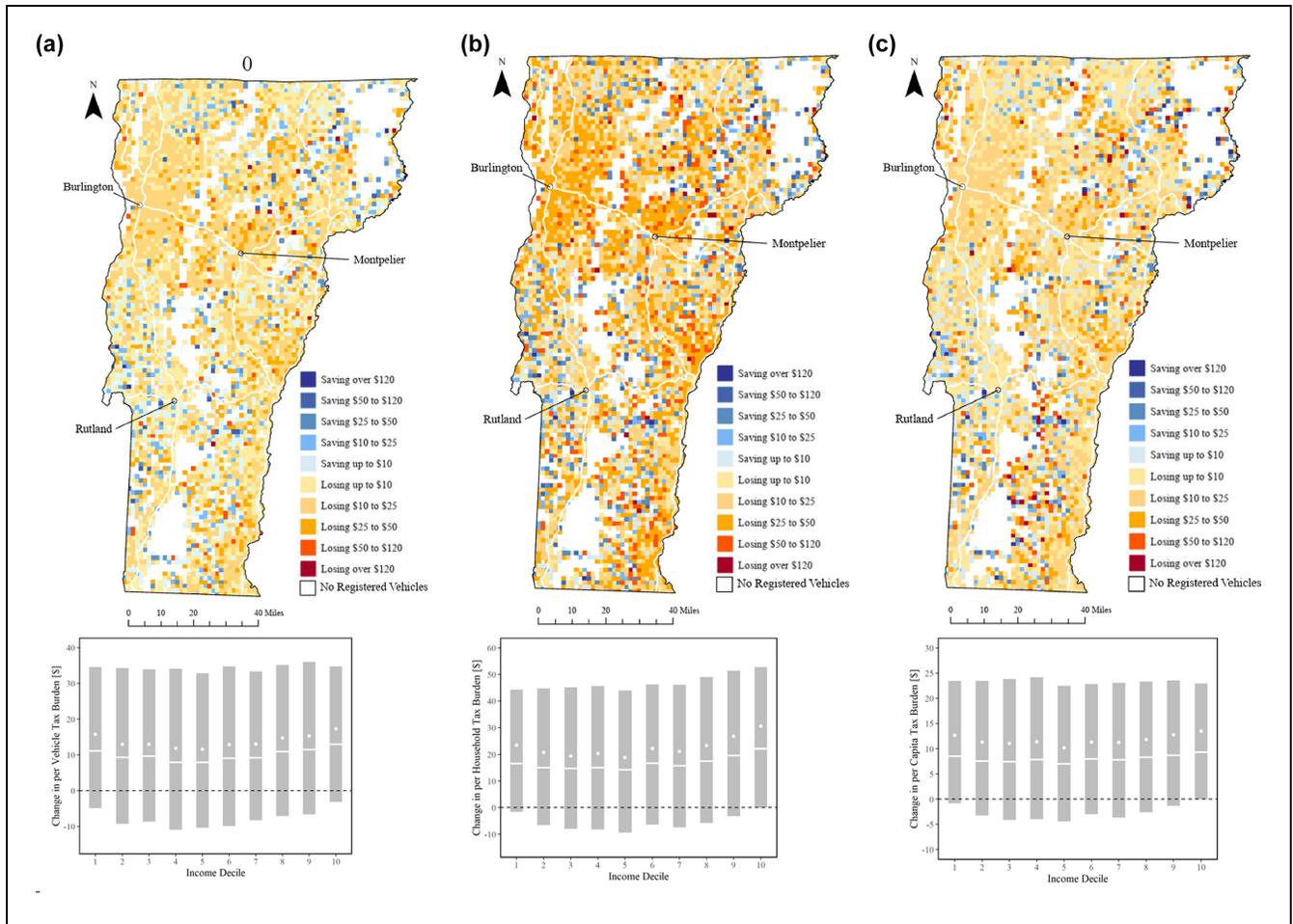
Figure 6. Annual change in tax burdens for mileage-based user fees replacing the gas tax: (*a*) per vehicle, (*b*) per household, and (*c*) per capita.

considered rural areas, were more likely to save money. The impact of community type is further examined in Figure 7. In all cases, those located in urban areas saw the largest cost increases.

Figures 5 and 6 contain box plots depicting flat fee and MBUF cost impacts varying with income. The general trend revealed that flat fees were more regressive, with either stable or decreasing cost differences (lower costs) as income increased. MBUFs were more progressive, with either stable or increasing cost differences (higher costs) as income increased.

Cost Variation by Race and Ethnicity

Cost differences between the gas tax and a flat fee or MBUF were also examined across races and ethnic groups (Table 4). There was little to no difference in annual household cost payments between all races and ethnicity categories as described by the census. Compared with the largest group in Vermont, meaning

White and non-Hispanic/Latino/Spanish, most other groups paid similar amounts or less per household per year for both flat fees and MBUFs. We found that only non-Hispanic Native Hawaiian/Pacific Islanders could expect to pay more on average compared with other races and ethnic groups. Their overall tax burden was approximately $5 per year higher under an MBUF than the second highest paying group (non-Hispanic White). Based on this analysis, there was little evidence to suggest there would be racial disparity in cost variation under an MBUF in Vermont.

Conclusions

We concluded that an MBUF fee would be a viable alternative to the gas tax in Vermont. Most households would see very small changes to their current annual gas tax payments. On average, Vermont households would pay an extra $23 per year. Rural and lower income households would generally see the smallest increases whereas
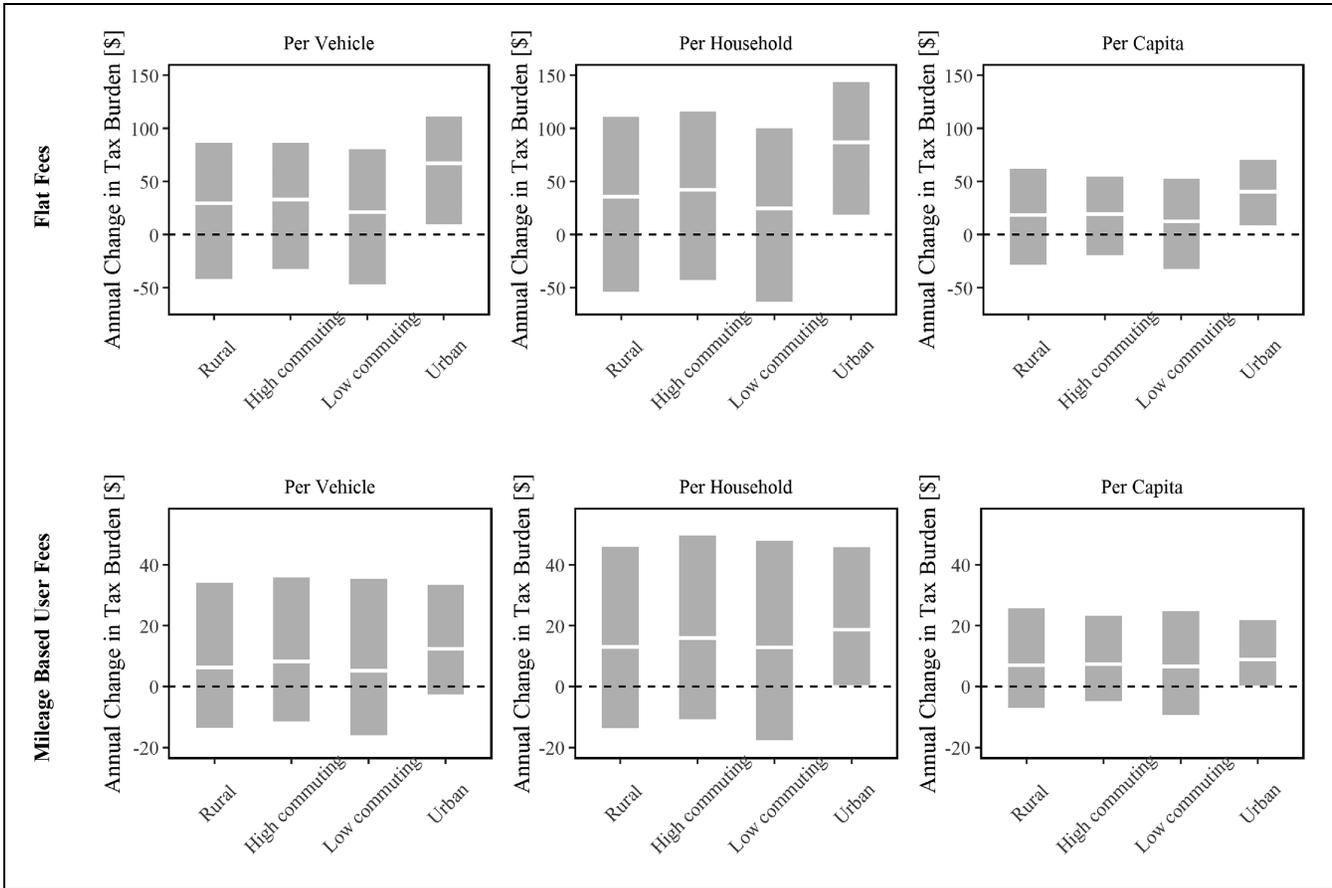
Figure 7. Annual change in tax burdens for flat fees and mileage-based user fees replacing the gas tax by community type.

Table 4. Mean Tax Burdens for the Gas Tax, Flat Fees, and Mileage-Based User Fees (MBUF) by Race and Ethnicity

Race	Gas tax ($)	MBUF ($)	Flat fee ($)
Hispanic/Latino/Spanish	243.27	266.78	294.76
White (alone)	255.34	277.12	299.38
African American/Black (alone)	211.11	236.22	280.78
Asian (alone)	215.89	242.04	289.72
Native American/Indian (alone)	247.50	268.91	290.03
Native Hawaiian/Pacific Islander (alone)	251.74	283.13	301.17
Other race (alone)	231.01	250.96	282.35
Two or more races	239.48	261.76	290.27

urban and higher-income households would see somewhat larger increases. Since rural households on average have much higher gas tax burdens than urban households, an MBUF would result in a somewhat more equitable distribution in rural user fees across community types. An MBUF is also somewhat more progressive (or less regressive) than the gas tax since lower income households would generally pay less than higher-income households, although this varies across community types. These findings align with those of past MBUF studies that have considered cost burdens across income groups and urban and rural communities; however, our results using a larger and more spatially refined data set revealed the heterogeneity in costs across the urban to rural continuum and the factors contributing to the observed broad spatial patterns.

We found that flat fees, on the other hand, would cause more extreme price variations, with the average Vermont household paying $47 more per year and larger incidences of extreme savings and losses. Furthermore, a flat fee would be a departure from the intent of the current gas tax to act as a road-user fee, and raises equity concerns insofar as it would charge vehicle owners the same user fee regardless of their use of public roads, including those who have minimized the amount they drive to save money or reduce their environmental impact. In this way, a flat fee fails to meet the benefit principle of equity.

Although an MBUF is attractive from a revenue generation and user fee perspective, implementation would face numerous challenges including various equity concerns. The public, alongside state and federal policy makers, are concerned about impacts on rural and low-income communities. With our robust and data-driven analysis it may be possible to "myth-bust" these general misperceptions. For example, it is possible to see on a map at a very fine spatial scale the expected change in costs in every community across the state using real data about the actual travel and vehicle ownership of individual Vermont households. This information could be used, as demonstrated in the Hawaii HiRUC study, in public education campaigns as a means of increasing support for an MBUF program.

Our findings also point to an additional concern with the design of revenue-neutral MBUF programs. A revenue-neutral MBUF in Vermont would, on average, increase the tax burden for most Vermont households. This occurs because commercial, medium, and heavy-duty vehicles would on average pay less. Commercial vehicles have much lower fuel economies than personal vehicles, a factor that is not used in the calculation of an MBUF. Future efforts to develop fair and equitable MBUF policies might consider separate personal and commercial MBUF rates that aim for revenue neutrality within each category to minimize the impact on households.

Overall, the gas tax, as it stands, does not provide a reliable source of transportation funding owing to its inability to adjust to inflation and failure to collect revenue from the exponentially increasing proportion of fuel-efficient vehicles. Finding a viable solution to the funding gap is an urgent matter. This analysis found that a switch from the Vermont state gas tax to an MBUF would offer minimal cost differences for households, be more progressive than the gas tax, and revealed no pressing equity concerns across communities or racial–ethnic groups. However, other implementation barriers remain before an MBUF can be set into policy, several of which revolve around public attitudes and assumptions about MBUFs. For one, many believe that switching from a fuel-consumption-based tax to a mileage-based tax will deter more fuel-efficient vehicle purchases. Many in the public also see MBUFs as an invasion of privacy and are concerned about being tracked, which results in political apprehension to move forward with the policy. Furthermore, our analysis did not consider any additional administrative costs related to implementing an MBUF, such as verifying and auditing the odometer readings or distributing more sophisticated mileage tracking devices. These costs could increase the relative costs of an MBUF compared with the gas tax. Future research and pilot programs should focus on addressing these additional barriers.

Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: C. Nelson, G. Rowangould; data collection: C. Nelson, G. Rowangould; analysis and interpretation of results: C. Nelson, G. Rowangould; draft manuscript preparation: C. Nelson, G. Rowangould. All authors reviewed the results and approved the final version of the manuscript.

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