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Effects of the Transportation and Climate Initiative Program in Maine: A Study of Rural and Urban Households

William Somes
william.somes@maine.edu

Jonathan Rubin
University of Maine, rubinj@maine.edu

THE UNIVERSITY OF MAINE
Margaret Chase Smith Policy Center

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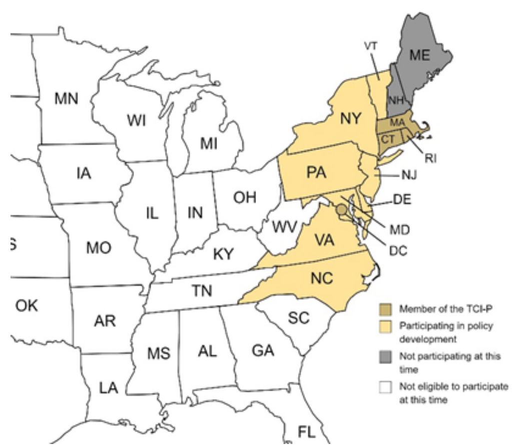
Over the past several decades, the global rise in atmospheric carbon and changes to the climate have meant continuing challenges to Mainers' way of life. Experts predict elevated temperatures and increased precipitation and freeze-thaw cycles will necessitate more frequent repairs to Maine's roads, culverts, and bridges. Such incidents could burden state agencies and place additional strain on Maine's economy.

As climate awareness continues to grow, many states are taking matters into their own hands. In 2005, a collection of states established the Regional Greenhouse Gas Initiative (RGGI) to curb emissions in the power sector. Using RGGI as a springboard, the Transportation and Climate Initiative (TCI) was formed five years later to mitigate emissions in the transportation sector. In Maine, the transportation sector is responsible for 53% of the state's carbon dioxide emissions, making it an important target for emission reductions.

With the release of the final MOU, the basic structure of the TCI (now called the Transportation and Climate Initiative Program, or "TCI-P") was solidified. Just four of 14 eligible jurisdictions signed the MOU, with eight states now participating in policy development. Two states, New Hampshire and Maine, have opted out of formal participation in the TCI-P citing concerns that projected increases in the price of fuel would disproportionately affect rural citizens. A map of the TCI-P region is shown in figure 1.

Figure 1: Map of the TCI-P Region



Note: this map was created with permission from mapchart.net.

This policy brief is a summary of our research examining the differential effects of the TCI-P on rural and urban households in Maine. The highlights of this research are presented here, with special attention given to changes in fuel consumption and CO_2 emission reductions as well as the equity implications of the TCI-P. The most visible effect of the TCI-P is the expected economic burden of \$52 to \$92 per year for the average Maine household. Our findings are summarized below:

- To determine households' responses to predicted fuel price increases of 5¢ to 9¢, we adapted short-run estimates of the price elasticity of demand for gasoline in Maine, finding a statewide (weighted) estimate of -0.8737. Estimates for rural and urban Maine were -0.9747 and -0.7473, respectively. We performed sensitivity analyses using elasticities 50% lower and 25% higher than these estimates.

- Statewide adapted price elasticity estimates show an average Maine household would reduce its consumption of gasoline by 1.8% to 3.3% in the short run depending on the change to the price of gasoline. Sensitivity analysis showed a maximum range of +/- 1.6 percentage points.
- Results showed a decline of 1.8% to 3.3% in metric tons of CO_2 from household gasoline emissions depending on the change to the price of gasoline. Sensitivity analysis showed a maximum range of +/- 1.6% of total household vehicle emissions.
- Findings indicated the TCI-P could result in some disparities in economic losses and burdens for rural households as compared to urban households. Depending on the change in the price of gasoline, rural households could face annual economic losses of $1 to $4 and economic burdens of $52 to $92. Urban households could face annual economic losses of $1 to $3 and economic burdens of $52 to $92. Sensitivity analysis showed a maximum range of economic losses and burdens of +/- $2. The similar range of values suggests that price elasticity is less important than households' quantity demanded of gasoline in determining economic loss and burden. On average, we found rural households consume 18 more gallons per year as compared to urban households.
- Disparities between rural and urban households are driven, in part, by differences in median household income. The median average income for rural households is $53,701 compared to $60,571 for urban households. Households were classified as rural or urban based on county residence.
- Results indicated Maine may face annual losses in gasoline tax revenue of $3.24 million to $5.84 million depending on the change in the price of gasoline. These figures represent short-run losses from changes in household consumption of gasoline only. Sensitivity analysis revealed a range of revenue losses 50% lower to 25% higher.

Revenues from allowance auction proceeds could generate $32.44 million ($32.29 to $32.74 million after sensitivity analysis) annually in the short-run given a 5¢ increase in the price of gasoline. Given a 9¢ increase, we estimated $31.95 million in auction revenues annually in the short-run ($31.68 million to $32.50 million after sensitivity analysis). These values assume a starting allowance price of $6.60 and represent revenues generated from household gasoline consumption only.

Efforts to achieve the goals laid out in Maine's Four-year Plan for Climate Action may require decision-makers to discuss how the TCI-P fits alongside state objectives. The present research can help inform this discussion.

Overview of the TCI-P

The TCI-P is a cap-and-invest program facilitated by the Georgetown Climate Center, aiming to reduce emissions in the transportation sector by 26% by 2032.[1] As a cap-and-invest program, the TCI-P sets a maximum quantity of emissions (in $MTCO_2$) and auctions off a limited number of allowances (to be determined in the final Model Rule) to state fuel suppliers. Fuel suppliers are then required to hold one allowance per $MTCO_2$ contained in affected fuel, which includes any retail gasoline and on-road diesel sold in a participating TCI-P jurisdiction.

When fuel suppliers purchase allowances, it is assumed they will try to pass all costs onto consumers, such that the price per gallon of gasoline will rise. Whether or not the full price of allowances is passed on depends on the demand and supply for gasoline and diesel. Recent estimates predicted a 5¢ to 9¢ increase in the cost per gallon of gasoline in 2023, assuming an allowance price of $6.60. These

"What is 'cap-and-invest?'"

Cap-and-invest is a term used for cap-and-trade programs like RGGI where the proceeds are dedicated towards actions to reduce carbon emissions. In its most basic form, cap-and-trade entails selling a limited number of carbon credits to polluters who may either use them to cover their own emissions or sell them to others.

forecasts are estimates; prices could be higher or lower depending on the demand for gasoline.

Given the potential for price variability, policy designers incorporated various price stabilization mechanisms to help ensure price increases remain within the 5¢ to 9¢ range. Two such mechanisms are emissions containment reserves (ECRs) and cost containment reserves (CCRs). These mechanisms moderate price fluctuations by removing (in the case of the ECR) or introducing (in the case of the CCR) allowances at the appropriate time.

Prices are further stabilized by multi-year compliance periods, which provide fuel suppliers additional time to meet allowance obligations given year-to-year variation in gasoline demand. Allowance banking and offsets also help to stabilize prices, and each are permitted under the draft Model Rule so long as certain requirements are met.

Investments & Benefits

When jurisdictions auction off allowances to fuel suppliers, this generates revenue that can be invested to meet TCI-P goals. These goals include reducing CO_2 emissions in the transportation sector, reducing particulate matter and other air pollutants, promoting economic growth (e.g., through job creation), and making clean transportation more accessible, among others.

While jurisdictions can allocate TCI-P proceeds as they see fit, the Georgetown Climate Center has made various recommendations to guide investment decisions. Based on these recommendations, participating jurisdictions could invest in things like vehicle electrification, public transit, or constructing active mobility infrastructure (e.g., bike paths).

The way auction proceeds are invested will determine the kind and extent of expected program benefits. For example, investments that prioritize active mobility infrastructure would result in greater health benefits from reduced air pollution, while investments prioritizing vehicle electrification would result in greater reductions in greenhouse gas emissions.

Apart from health benefits, a recent report from the Georgetown Climate Center estimated that the TCI-P could result in a regional $590 million annual increase in GDP and 2,660 new jobs per year, assuming at least 13 eligible jurisdictions participate.[2]

Greater participation in the TCI-P region would lead to greater benefits.

Equity Implications

The TCI-P may impact some Mainers more than others. In an interview from December 2020, Governor Mills noted her concern that increases in the price of gasoline would fall harder on low-income residents. Trucking and logging companies in Maine have raised similar concerns for their own industries.

Equity concerns such as these are not unique to Maine. In fact, the focus on equity has led to efforts on behalf of TCI-P policy designers to mitigate unbalanced impacts. The MOU, for example, requires that 35% of TCI-P revenues be dedicated to "overburdened and underserved" communities. It also contains a provision for an Equity Advisory Body to provide input and oversight on TCI-P policies, including on how revenues are invested.

Study Purpose and Scope

The purpose of this study was to determine the economic effects of the TCI-P on Maine households. This involved estimating multiple factors, including:

1. The short-run, household price elasticity of demand for gasoline in rural and urban Maine
2. The expected change in gasoline consumption from the TCI-P
3. The change in CO_2 emissions associated with expected changes in gasoline consumption
4. The economic loss and burden from expected reductions in household gasoline consumption
5. The change in tax revenues resulting from reductions in household gasoline consumption
6. The net revenue gain (after-tax) from allowance auction proceeds

Important to note is that we studied the TCI-P's impact on *household* gasoline consumption only. We did not study the economy-wide impacts of the TCI-P, nor did we study the effects of the TCI-P on diesel consumption. Similarly, we did not analyze the reductions in CO_2 emissions, economic losses and burdens, tax revenues, and allowance auction proceeds associated with diesel consumption.[3]

Results

Data

We collected data from the Maine Department of Environmental Protection (MeDEP), the American Community Surveys (ACSs), and the Georgetown Climate Center. The MeDEP supplied data on 2017 fuel consumption by vehicle type, which was instrumental in estimating reductions in the household consumption of gasoline. The ACSs provided the demographic data needed to adapt estimates of the price elasticity of demand for gasoline. The Georgetown Climate Center provided estimates of the fuel price increases expected to result from the TCI-P. We also collected data from Google Maps, the Bureau of Motor Vehicles, the Maine Department of Transportation, and the American Automobile Association for similar purposes. The Transportation Energy Data Book from Oak Ridge National Laboratory provided additional information needed to convert gasoline consumption into CO_2 emissions.

Price Elasticity

The price elasticity of demand is a measure of one's sensitivity to changes in the price of a good or service. In relation to the TCI-P, price elasticity represents the degree of responsiveness in the quantity demanded of gasoline expected to result from a 5¢ to 9¢ increase in the price of gasoline.

Since the present research sought to determine the differential effects of the TCI-P on rural and urban households, a separate price elasticity estimate was required for both regions. To determine these respective elasticities, we adapted estimates from Spiller, Stephens, and Chen (2017), who divided households' price elasticity into eight different characteristics, including:

1. Household size
2. Vehicles per household
3. Vehicle fuel economy
4. Distance to the nearest metropolitan statistical area (MSA)
5. Gasoline price
6. Average commute time
7. Income
8. Region (rural or urban)

Estimates are shown in abbreviated form in table 1 and in full in the appendix.

Perhaps the most common way to estimate the price elasticity of fuel demand is through the use of reduced-form models. These estimates have typically generated short-run (1-5 years) elasticities ranging from -0.2 to -0.3.

Table 1: Elasticities by region

Rural	Urban	Statewide
-0.975	-0.747	-0.874

Note: Adapted estimates of the price elasticity of demand for gasoline represent short-run (1-5 years) sensitivity in household consumption to changes in the price of gasoline. Elasticities reflect a gasoline price of $2.39.

Note that the estimates used in the present research are higher (more elastic) in absolute value.

There are several reasons for this, one being that the study on which the present research was based used household-level data. Studies using household-level data tend to produce higher elasticity estimates,[4] typically ranging from -0.43 to -0.67.

To check the validity of results, we conducted an asymmetric sensitivity analysis using elasticities 50% lower and 25% higher than those given in table 1. These results are reported in the following subsections.

Gasoline & Emission Reductions

We estimated the change in households' quantity demanded of gasoline using the statewide elasticity estimate of -0.874 given above, assuming either a 5¢ or 9¢ increase in price. Estimating these factors was an important step toward determining the broader effects of the TCI-P in Maine, discussed below.

Given a 5¢ price increase, we estimated gasoline consumption would decline by 10.79 million gallons (19 gal/household) in the short-run. Multiplied by an emission factor of 0.008507 $MTCO_2$/gal of gasoline,[5] this equals 91,778 $MTCO_2$, or a 1.8% decline in household vehicle emissions from gasoline. We obtained a range of possible gasoline and emission reductions through sensitivity analysis, which showed gasoline could decline by 5.39 million to 13.49 million gallons, or roughly 10 to 24 gal/household, respectively. This corresponds to emission reductions of 45,889 $MTCO_2$ (0.9%) to 114,723 $MTCO_2$ (2.3%).

Given a 5¢ price increase, we estimated that consumption of gasoline would decline by 19.46 million gallons (35 gal/household), or 165,565 $MTCO_2$ and a 3.3% reduction in household vehicle emissions from gasoline. Sensitivity analysis revealed declines in gasoline consumption ranging from 9.73 million to 24.33 million gallons in the short-run, or roughly 17 to 44 gal/household, respectively. This corresponds to emission reductions of 82,782 $MTCO_2$ (1.7%) to 206,956 $MTCO_2$ (4.1%). Results are summarized in table 2.

Economic burden is defined as the **direct change in consumer wellbeing from an increase in price.**

Economic loss is defined as the indirect **change in consumer wellbeing** from a reduction in market activity that households value.

Economic Loss & Burden

We estimated economic loss and burden for both rural and urban households to determine the potential for heterogeneous impacts across different sections of the Maine population. Economic loss represents the decline in consumer wellbeing when price increases cause households to purchase less gasoline than they otherwise would. Economic burden represents the decline in consumer wellbeing when households spend more per unit of gasoline. Economic loss and burden are illustrated in figure 2 below.

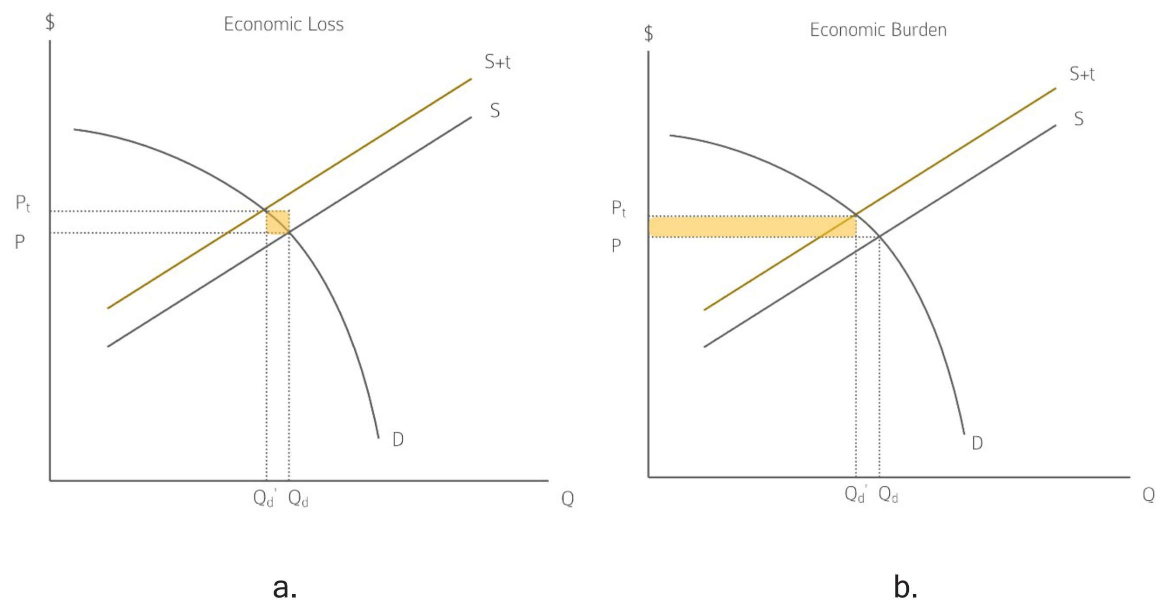
Results indicate little variation in either economic loss or burden for rural and urban households given the range of price elasticities we considered. We estimated that a 5¢ increase in the price of gasoline would lead rural households to face economic losses of just over $1 per year, while urban households would face losses of just under $1 per year. The economic burden for rural households was also comparable to that of urban households, with both facing burdens of roughly $52

Table 2: Gasoline and Emission Reductions

Price Change	Change in Consumption (millions of gallons)	Change in Emissions. (MTCO2)	% Change in Emissions	% Range in Emissions
5¢	10.79 million	91,764	1.8%	0.9% to 2.3%
9¢	19.46 million	165,552	3.3%	1.7% to 4.1%

Note: The first column shows two potential price increases that could result from the TCI-P. Given these price increases, the subsequent columns show a range of expected gasoline and emission reduction outcomes. The final column provides a percentage range of emission reductions (and therefore a range in consumption) using elasticities 50% lower and 25% higher than those given in table 1.

Figure 2: Economic Loss and Burden



Note: When fuel suppliers purchase allowances to cover the emissions of affected fuel, it is assumed they will attempt to pass costs onto households. The supply curve therefore shifts up by amount *t*, in proportion to the cost of allowances. As graphs a. and b. show, these efforts are only partially successful, as households respond by reducing their quantity demanded of gasoline. The result is a price increase of ($P_t - P$) instead of the full amount ***t***. Thus, the cost of allowances is shared by both fuel suppliers and households, with households facing 5¢ to 9¢ increases in the price of gasoline in the case of the TCI-P. Note also that the demand curve is depicted as being concave to the origin. This is true only if households become more price elastic as prices rise, as suggested in Spiller, Stephens, and Chen (2017).

The upper bound of the economic (or "deadweight") loss faced by households is shown by the yellow-shaded region in panel a. Economic loss represents the costs associated with a reduction in market activity when the cost of gasoline rises by amount ($P_t - P$). The upper bound of the economic loss is calculated following Spiller, Stephens, and Chen (2017) for small, incremental changes in the price of gasoline, as would be expected from the TCI-P. The economic burden faced by households is shown by the yellow-shaded region in panel b. The economic burden represents the share of household expenditures on fuel that result from an increase in the price of gasoline. It is considered a more direct measure of consumer welfare than economic loss.

per year (approximately 2.1% of annual fuel costs and 0.6% of average costs of driving for households from either region). Given a 9¢ increase in the price of gasoline, we estimated rural households would face economic losses of under $4 per year, while urban households would face losses of under $3 per year. We found that the economic burden for rural households to be just over $92 per year in the short-run, and for urban households, just under $92 per year. These figures for the economic burden represent 3.6% of fuel costs and just over 1.0% of the total costs of driving for the average Maine household from either rural or urban Maine.

Sensitivity analysis revealed little deviation from these results. Given a 5¢ price increase, economic loss ranged from 54¢ to just over $1 per year for rural households and 40¢ to just over $1 per year for urban households. Economic burden for a 5¢ price increase ranged from $52 to $53 per year for rural households and from $51 to $52 per year for urban households.

Given a 9¢ price increase, sensitivity analysis showed economic losses ranging from $2 to $4 per year for rural households and from $1 to $3 per year for urban households. Analysis showed that economic burdens given a 9¢ price increase could range from $91 to $94 per year for rural households and from $91 to $93 per year for urban households. As a percent of households' fuel and total driving costs, sensitivity analysis revealed no meaningful deviation from initial results given a 9¢ price increase.

Results for economic loss and burden are similar for three reasons:

1. The price change expected from the TCI-P is relatively small.
2. While elasticity estimates differed substantially between rural and urban Maine, in this case we found elasticity plays a lesser role in determining economic loss and burden than households' quantity demanded of gasoline.
3. Our analysis found rural households consume 18 gallons more per year as compared to urban households.

See "Study Limitations" for more information.

State Tax Revenue

The gasoline tax in Maine is 30¢ per gallon, plus an additional .01¢ per gallon in fees.[6] If households reduce their quantities demanded of gasoline in response to price increases, state tax revenues will fall proportionately.

We found that a 5¢ increase in the price of gasoline would result in losses of $3.24 million. A 9¢ increase would result in losses of $5.84 million.

Sensitivity analysis found that a 5¢ increase in the price of gasoline could result in losses of $1.62 million to $4.05 million and that a 9¢ increase could result in losses ranging from $2.92 million to $7.30 million.

Allowance Auction Proceeds

The effects of tax revenue reductions on the Maine economy may be contrasted with auction proceeds generated by the TCI-P.[7] We estimated the portion of proceeds expected from household consumption of gasoline in Maine.

In a recent report from the Georgetown Climate Center, allowances for the TCI-P were predicted to start at $6.60 per $MTCO_2$ in 2023. Given this price, we found that the TCI-P could raise $31.95 million to $32.44 million annually depending on the change in the price of gasoline in the state.

Given a 5¢ increase in the price of gasoline, sensitivity analysis revealed that the TCI-P could generate auction proceeds of $32.29 million to $32.74 million. A 9¢ increase in price would result in a lower stream of proceeds due to households' higher elasticities and lower consumption of gasoline. This is an unexpected result arising from our high elasticity estimates. Sensitivity analysis showed auction proceeds could range from $31.68 million to $32.50 million given a 9¢ price increase.

Responding to Equity Concerns

The TCI-P addresses important questions about how to cut greenhouse gas emissions in one of the most polluting sectors in the economy. However, it raises equally important questions about how to best serve the overburdened and underserved members of our communities. Responding to these questions can be challenging.

The 35% equity mandate mentioned above is one response that seeks to find middle ground between both issues. Yet questions remain as to how exactly this portion of auction proceeds should be spent.

One way to guide investments of TCI-P proceeds would be to follow the transportation goals already laid out in Maine's Four-year Plan for Climate Action—some of which may effectively address equity concerns. Increasing the fuel economy of Maine's vehicle fleet, for example, would ensure that those who drive the most (rural households) would receive the preponderance of benefits, in this case through reduced expenditures on gasoline. Providing rebates for used and new high efficiency vehicles would be one way to facilitate this solution, as the Maine Climate Council recommended.

Expanding access to public transit is another goal listed in Maine's Four-year Plan for Climate Action, with even greater potential to address equity concerns. A recent paper from Gillingham and Munk-Nielsen (2019) found that, in settings where access to public transit is universal, a gas tax with a uniform redistribution of revenues given to each member of society is progressive in terms of vertical equity. This novel finding suggests a positive relationship between the accessibility of public transit and the progressivity of a program like the TCI-P.

However, expanding public transit may not be cost-effective in some of the most rural parts of the state. This solution may also fail to address the unequal burden rural businesses (particularly within the logging and trucking industries) would face from the TCI-P. While TCI-P proceeds may be used to fund rebate programs for more fuel-efficient trucks, these rebates may still prove insufficient for those businesses operating on the smallest margins. In such contexts, alternative solutions may be necessary to ensure the TCI-P does not create disproportionate impacts. Future research should investigate the viability of the following policy proposals as potential supplements to existing transportation goals:

1. A portion of TCI-P proceeds could be redistributed in the form of an annual tax credit to households that meet specific criteria: e.g., income, commute distance, household size.

2. A portion of TCI-P proceeds could be set aside to pay for tax breaks for industries disproportionately affected by the TCI-P, such as the logging and trucking industries in Maine.

3. A portion of TCI-P proceeds could fund the implementation of fuel-saving technologies or other strategies utilized by the Environmental Protection Agency's SmartWay program.

Conclusions

Considerations for Policymakers

In addition to equity concerns, several other considerations may guide policymakers' decision whether or not to join the TCI-P in the future:

- The TCI-P will contribute modestly to the state's mandated emission reduction goals of 45% by 2030 and 80% by 2050.
- Relatedly, the TCI-P could serve as a funding source to help Maine meet the transportation goals outlined in the Four-year Plan for Climate Action.[8] There is currently an annual $232 million shortfall in funding for transportation-related projects, and funding needs will only increase as the state moves to meet these goals.
- Policymakers may consider how a patchwork TCI-P could impact program effectiveness. For example, if Maine decides to join the TCI-P but New Hampshire, Vermont, or other states do not, some households and interstate truckers could choose to fill up outside state borders to avoid price increases. The average price of motor fuel in New Hampshire is somewhat lower than it is in Maine (approximately 9¢ more per gallon). For truckers or households living on or near the New Hampshire border, this discrepancy may prove sufficient to alter consumption behavior. On the other hand, residents living on or near the Canadian border would continue purchasing their gasoline in Maine, as gas prices in the two bordering provinces of Quebec and New Brunswick are, based on current provincial averages, at least 33% higher.

Responding to Public Opinion

Public opinion polling from Climate Nexus and the Yale Program on Climate Change Communication (YPCCC) reported that 56% of Maine survey respondents expressed at least some support for the TCI-P, compared with 26% that expressed at least some opposition.[9] Majority support may provide additional justification to adopt the TCI-P. Still, policymakers must take care in responding to the public's concerns. Utilizing the following messaging and communication strategies may help policymakers increase public support for the TCI-P:

- Maine trails a majority of states in gas tax rates and is ranked 27th nationally. Highlighting this point may soften remonstrances over gas price increases.
- Policymakers should transparently state the benefits and costs to be expected by both rural and urban households, as well as their plans to distribute them.
- While communicating about the TCI-P, policymakers should: (1) emphasize the contemporary relevance of climate change, (2) appeal to social norms, and (3) suggest simple actions that are implementable in everyday life.

The transportation sector remains a significant source of greenhouse gas emissions in Maine. While the TCI-P may contribute to the state's transportation goals, its success or failure will largely depend on how policymakers address Mainers' concerns about equity. Doing so will require care and ingenuity to develop the right policy solutions, the right messages, and the right communication strategies.

APPENDIX: Short-run Weighted Elasticities by Household Characteristic

Maine Average Elasticity Estimate

Category	Maine Average	Weights	η
Household size	2.33	9.5%	-0.77030
Vehicles per household	2.06	13.5%	-0.84710
Average MPG	21.76	13.5%	-0.89745
Distance to MSA	59.99 km	9.5%	-1.61901
Gasoline price	2.39	13.5%	-0.60031
Average commute	24 min.	13.5%	-0.87400
Household income	$55,425	13.5%	-0.72557
Rural or urban?	Both	13.5%	-0.84622
Weighted average		100.00%	-0.87372

Maine Rural Elasticity Estimate

Category	Rural Average	Weights	η
Household size	2.32	9.50%	-0.76920
Vehicles per household	2.06	13.50%	-0.84710
Average MPG	21.76	13.50%	-0.89745
Distance to MSA	80.97 km	9.50%	-2.50770
Gasoline price	$2.39	13.50%	-0.60031
Average commute	24.73 min.	13.50%	-0.87984
Household income	$53,700.96	13.50%	-0.71109
Rural or urban?	Rural	13.50%	-0.97800
Weighted average		100.00%	-0.97467

Maine Urban Elasticity Estimate

Category	Urban average	Weights	η
Household size	2.35	9.50%	-0.77250
Vehicles per household	2.06	13.50%	-0.84710
Average MPG	21.76	13.50%	-0.89745
Distance to MSA	30.16 km	9.50%	-0.50500
Gasoline price	$2.39	13.50%	-0.60031
Average commute	22.96 min.	13.50%	-0.86568
Household income	$60,571.24	13.50%	-0 .76716
Rural or urban?	Urban	13.50%	-0.65900
Weighted average		100.00%	-0.74732

Methods

Methods centered around in two main areas: (1) creating a classification scheme for rural and urban households and (2) adapting short-run estimates of rural and urban households' price elasticity of demand for gasoline.

The rural/urban classification schemed was based largely on definitions from the U.S. Census Bureau, which considers an "urbanized area" to contain 50,000 or more people. In the present research, Maine's three Metropolitan Statistical Areas (MSAs) (Bangor, Portland-South Portland, and Lewiston-Auburn) were used as proxies for Maine's urbanized areas, which are identical excepting the cities of South Portland and Auburn. Specifically, households located within counties containing the principal cities of each MSA were considered "urban," whereas households located outside these counties were considered "rural." As such, Androscoggin, Cumberland, and Penobscot counties were all classified as "urban," while Aroostook, Franklin, Hancock, Kennebec, Knox, Lincoln, Oxford, Piscataquis, Sagadahoc, Somerset, Waldo, Washington, and York counties were classified as "rural." See the sidebar titled "Study Limitations" for a discussion of how this classification scheme impacted study results.

As described above, estimates of the price elasticity of demand for gasoline were modified according to eight different household characteristics, including:

- *Household Size*. Household size for rural and urban Maine was determined by summing the weighted average household sizes in each county according to their rural and urban designation. Counties were weighted according to their relative share of the rural or urban population.
- *Vehicles Per Household (VPHs).* The VPHs characteristic was calculated by dividing the number of registered household vehicles by the number of households in Maine.
- *Average Fuel Economy (MPG)*. MPG was calculated in several steps. First, an average vehicle miles traveled (VMTs) estimate from the Maine Department of Transportation was multiplied by the number of licensed drivers to estimate total annual VMTs in Maine. This value was then divided by the total number of gallons of motor fuel consumed by Maine households in 2017 (including gasoline and diesel).
- *Distance to the Nearest MSA*. Distance to the nearest MSA for rural and urban Maine was calculated by summing the weighted distances (in kilometers) from the center of population of each county to the closest MSA. Distance was weighted according to each county's relative share of the rural or urban population.
- *Gasoline Price*. Gasoline price information was obtained from the American Automobile Association.
- *Commute Distance*. Household commute distance for rural and urban Maine was obtained at the county level from the American Community Survey 5-year estimates from 2014-2018 and was weighted according to county population.
- *Median Household Income*. Median household income for rural and urban Maine was calculated in the same way as the "commute distance" characteristic.
- *Rural Versus Urban.* The classification scheme used to discriminate between rural and urban Maine is described above.

A more thorough elucidation of research methods can be found in the original study, published here.

Study Limitations

Several limitations impact the findings of this study. The first is the lack of ideal data for the estimation of three household-specific characteristics (vehicles per household, MPG, and town-specific gasoline prices) for rural and urban Maine. We used statewide averages instead, as shown in the appendix.

Another limitation is a lack of definitive guidance on the relative importance of household characteristics in determining a household's sensitivity to changes in the price of gasoline. However, as sensitivity results show, this is not likely to have an important impact on our equity calculations.

A final limitation is the method we used to differentiate between rural and urban households. This method resulted in less variability in individual households' quantity demanded of gasoline than may exist in practice, considering the potential for underlying variability in household behavior. Our method of classifying households, while useful for highlighting differential effects, tends to underestimate the economic impacts of the TCI-P on rural households that drive long distances.

To illustrate, we calculated the economic burden for households that consume 25% more and 25% less gasoline than the average Maine household. The average household consumed 1,057 gallons of gasoline in 2017. Using the statewide elasticity estimate of -0.8737, we found that households who consume 25% more gasoline (1321 gal/yr.) would face a short-run, annual economic burden of $65 to $115 depending on a 5¢ or 9¢ increase in the price of gasoline, respectively. Households who consume 25% less gasoline (793 gal/yr.) would face an economic burden of $39 to $69 depending on a 5¢ or 9¢ price increase, respectively.

We believe, and the numbers confirm, that a household's burden from the TCI-P will be driven mainly by its VMTs, not its degree of sensitivity to changes in the price of gasoline.

Endnotes

1 Recent modeling results predict that emissions in the transportation sector will decline by 24.3% whether states join the TCI-P or not.

2 At the time, North Carolina was not eligible to participate. These figures therefore assume participation of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, and the District of Columbia.

3 The reason for excluding economy-wide effects of the TCI-P should be clear from the study purpose given above. Excluding the effects associated with diesel consumption was deliberate and motivated by the fact that diesel comprises just 2.1% of households' consumption of motor fuel in Maine. Calculating the effects associated with diesel consumption would have also required a customizable estimate of the price elasticity of demand for diesel fuel at the household level, information that was unavailable at the time of this study.

4 This claim is based on research from Graham and Glaister (2002), as cited by Spiller, Stephens, and Chen (2017).

5 The emission factor used in this study was calculated by multiplying the amount of carbon in a gallon of E10 (2,347 grams) by the ratio of molecular weights for carbon and CO2 (44/12). This number was then divided by 1,000,000 so that it could be expressed in metric tons.

6 The 30¢ gas tax can be found in 36 M.R.S. §2903(1) (2019). The .01¢ fee can be found in 38 M.R.S. §551(4A-1) (2015).

7 It is important to note restrictions on TCI-P revenue allocation will likely preclude replacing losses to the General Highway Fund arising from decreased gasoline tax revenues.

8 While the TCI-P would generate revenues for clean transportation-related projects, policymakers should weigh these revenues against so-called "leaky bucket" costs associated with revenue transfers. These costs include things like the distortionary effects of taxes (to the extent that the TCI-P functions as a tax) and the administrative costs associated with the distribution of benefits.

9 Margin of error = +/- 6-9%.